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Gains, Losses and the Future

Mr. Lemoine's short report on the present position of steel castings, given before the International Foundry Congress in Paris and published elsewhere in this issue, is extremely useful, as it focusses attention on the general subject of industrial gains and losses. Many promising tendencies fail to stay the course, for reasons not easily discernible. For instance, cast-iron farming equipment and agricultural machinery parts have sometimes been replaced by sheet metals, and other materials, but without lasting success. This is due to the following line of reasoning on the part of the farmer. Farm sheds cost money for both erection, maintenance and rates. Therefore, their capacity has to be reserved for equipment consisting mainly of wood. The farmer assumes that the deterioration of cast iron through exposure in the open field represents less monetary value than the space it would occupy in a covered shed. It is thus apparent that amongst a very important class of user, cast iron has acquired a goodwill which is deserving of careful consideration by both the agricultural engineer and foundryman. The slogan, "No need to store under cover," is more impressive as a sales point than a printed card of instructions, "How to Use," to be hung up in a barn.

High-duty cast iron is in certain directions making inroads into fields previously held exclusively by manganese steel, and already much progress has been registered in the cement industry. Whether this will extend to such components as dredger buckets and crusher rolls remains to be seen. Much co-operation still remains to be effected before a complete solution is achieved. In general, the science and practice of the heat-treatment of iron castings is not too well understood, and as such a department demands supervision by a skilled metallurgist, we suggest that there is room for the development of firms which would heat-treat castings for the trade. Firms catering in a similar manner for the steel industry have long been in existence.

Mr. Lemoine very rightly drew attention to the potentialities shown by "hybrid" cast crankshafts. Whether these be steel or iron is a matter of indifference, as even the latter type are made in iron foundries by steel making methods, often under quantity-production conditions. The factor which requires underlining is that here is an engineering component recognised as being of first-rate importance as to finish and mechanical qualities which has been won for the foundry at the expense of the forge. It is a development well capable of extension into fields other than the motor-vehicle industry. Generations of engineers have designed plant on the premise that, for the static components, cast iron is eminently satisfactory, but for moving parts steel has to be used. The doubt thrown upon this well-established custom by the newer developments must be exploited by the foundry industry, first as a research measure, and finally by the whole of the industry's co-operative commercial force. What is now but a molehill may well become a mountain in the future.

A Problem in Training

The chairman of the governing body of the British Foundry School referred at the recent annual meeting to the problem of ensuring a sufficient supply of students for the school. The number required may be regarded as between ten and fifteen per annum; the latter number is as many as can be dealt with unless the staff is increased, while the former ensures a suitable maximum cost per student-hour by dividing the total expenses over an appropriate number of students. The sudden improvement in trade makes the release of suitable men very difficult, and at the same time creates a demand for more trained men. In some cases the cost of maintaining the student is a real consideration for smaller firms, and the governing body would therefore be prepared to consider applications from suitably educated young men who would be prepared to enter the industry by obtaining, say, a year's practical experience as a preliminary to taking the school course. There should be little difficulty in arranging for foundries to receive such young men for the preliminary period, and to give them the opportunity of working on the floor. Neither pupil nor employer would have any obligation to each other at the end of the period, and the former would take the course at his own expense, assisted possibly by his local education authority. The problem of absorbing such men would have to be dealt with, but we imagine that a young man who proved his ability would have little difficulty in securing employment, possibly where he served his apprenticeship period. Every employer knows that in a foundry there are needed qualities of common sense, ability to deal with people, refusal to be discouraged by failure, and so on, which no certificate can guarantee. Rather than risk getting a man who may lack them even while having practical or technical ability of a high order, he usually prefers to appoint someone from inside his own organisation whom he knows. Our advice, therefore, to young men looking for a career in this field is to get into the foundry and show what they can do, for a scheme on the above lines is being considered, apart from short courses, which may be of service to the men who cannot get away for the full year's course.

The Rally in Spelter

By Onlooker.

There have often been long spells in the history of spelter when it has cut but a sorry figure alongside the other members of the non-ferrous group, but this year the metal has really put up a very good show. Early in January the price was well below lead, but at the height of the boom it went ahead of that metal and touched £37 per ton, the highest level registered by spelter for a very long time. A slump followed, however, for the market was riddled with speculation, and as soon as the change in sentiment came there was a wave of selling which continued until the bottom was reached in mid-June at £19 7s. 6d. Not unnaturally faith in the future of spelter was sadly shaken, for even when the quotation had gone below £20 it was reported that the market was threatened with liquidation of a big bull account as a result of which a further fall might occur. This did not materialise, and although there was actually a modest improvement, consumers were not persuaded to abandon their cautious policy.

Just prior to the August bank holiday, and in the middle of what is regarded as a very quiet time of the year, a sudden rally carried the price over £25 per ton. This event certainly took consumers by surprise for many buyers were absent on holiday. Much of the buying which caused the rise, probably the bulk of it, was speculative in origin and the demand was probably met by the producers who had not been selling much of late to users. The mainspring of the whole movement was, of course, provided by the news regarding shipments of spelter from Europe, and possibly from this country, to the United States, where there exists an acute shortage, particularly of high-grade qualities. Whether this development justified a rise such as occurred last week-end remains to be seen; probably a good deal depends on how much metal is actually shipped across the Atlantic, but to make the matter a paying proposition a spread of getting on for £10 between the U.S. price and the London parity is essential. The freight is not heavy but there is an import duty of 1¾ cents per pound on foreign spelter entering America, and this works out at nearly £8 per ton, so that unless the importer elects to pay, there is a good deal in the way of transactions being carried through on a profitable basis for the exporting houses on this side.

Whatever the possibilities or probabilities of the situation, the facts are that in New York spelter has risen to 7¼ cents and in London has again climbed over lead, with every appearance of staying above it since the latter does not appear to be in such a good position as it was a few weeks ago. More important still, perhaps, there has been a revival of interest in spelter, and even though some reaction occurs this metal has enjoyed a much needed boost which should stand it in good stead in the autumn when trade buying ought to come along. As a matter of fact the prolonged abstention of consumers is rather surprising, and it looks as if in the early months of this year they must have bought a good deal more than was supposed at the time. However, a buying wave, even though of modest dimensions, is indicated for the near future. The rate of consumption in spelter is good, and probably up on last year, for general trade has expanded and the galvanisers are certainly busier than they were. The manufacture of brass in connection with munitions is on the up-grade and will doubtless continue to expand as the Government's programme develops further, while ordinary commercial orders are also fairly good. The outlook for spelter is favourable.

E. R. & F. Turner, Limited, engineers and iron-founders, of Ipswich, have just celebrated their centenary.

Metal Patternmaking

By H. R. Thomas.

The standardisation of components and their quantity-production made possible by the machine moulding methods adopted in modern foundry practice, call for more robust pattern equipment than was necessary in former years. If, prior to the introduction of machine moulding, a few hundred castings of any one design were required, it was considered economic to make a standard pattern of mahogany or other suitable hard wood, and it is only in comparatively recent years that metal patterns have become a necessity. Even in the old days patterns of some components of a fragile nature were made in iron, but these were the exception rather than the rule. Although cast iron was the first metal used in patternmaking it is now practically superceded by a special pattern alloy, brass or an aluminium alloy.

There are wide differences of opinion as to the relative merits of each of these materials for patterns, and the choice for any particular job is governed by its nature and size. Where the pattern is fixed to the machine-table, the choice often falls on brass or a special pattern alloy of lead, tin and antimony. The virtue of the latter is its non-shrinkable property, which allows a wood pattern, originally made for production, to be used if necessary as a master pattern, thus saving the expense of a special pattern for this purpose. Patterns in this material are easily worked, and the alloy makes a smooth face but is very heavy, a drawback which is of no moment in jobs that are secured to the machine-table. Patterns in brass, like those in the special alloy, carry a very smooth face, but are more difficult to work, and often require machining to give the best results. In use, a brass pattern appears to improve by constant wear, the friction of the mould on withdrawal apparently tending to smooth it. Patterns and pattern plates are often made of an aluminium alloy, and if the pattern plates are used apart from a machine. they are more easily handled by the operatives than a heavier metal, with a consequent increase in output. Unfortunately, aluminium patterns have a tendency to tarnish after being in contact with damp sand, and should be shellac-varnished to give the best results.

After the choice of a suitable material has been settled, the question arises as to where the pattern shall be made, since a small foundry could not carry a staff of metal patternmakers. Such a foundry may, however, be attached to an engineering shop, and would possess the ordinary wood-working patternshop. Should the patternmaker who has made the wood master pattern clean up the metal pattern, or should the metal pattern be left with a machining allowance and the tool room of the engineering department finish it? The author knows of shops where all the metal patternmaking is done by the ordinary patternmakers, while in other shops the patternmaker makes only the master pattern and a detailed lay-out, the tool room finishing the pattern to the drawing supplied. In the writer's experience, the former method yields the best results, as it has been found that it is more difficult to develop a patternmaking mentality in a tool-room worker than a metal-working technique in a patternmaker. Cases could be cited in which a set of patterns was completely spoiled by the tool-room, it being very difficult to impress upon them the importance of taper, fillets in corners and the other many smaller details of a good pattern. It is therefore suggested that if any metal patterns are required, it will be found more economical for the patternmakers to be responsible for the metal as well as the wood-working side of their craft rather than to allow metal workers without any patternmaking sense of foundry requirements to attempt to produce the metal patterns.

Random Shots

Feeling in need of a change of air and environment during this hot weather—in short, wishing to escape from the sight of old iron and pigs, "Marksman" has betaken himself into the country only to find himself surrounded by—well—by more old iron and pigs, with sago pudding just to serve as a reminder of core oils.

The journey into the country involved an hour's run through the East End of London, but far from finding this a dreary process, it was fraught with interest, for this time someone else was driving and the passenger had two eyes free with which to look around him. On the Mile End Road there was a car for sale for £1; a block of old houses was being pulled down and demolition was by Wackett! There were homes built by Holmes, a draper named Bodger, and a very Tame library. One builder promised to provide the "House of your dreams" for 10s. 6d. per week. His nightly prayer must have been that you would not dream that you dwelt in marble halls, but rather confined your aspirations to castles in the air.

Getting further into the country, someone, with a very human understanding, had made two pathways through the fields—a hundred yards apart. One was marked "Public Footpath" and the other "Footpath for Lovers"! In one field you could have flights from 5s., but on looking at the 'plane which was to take you up the giddy heights, you soon realised that you could get frights for nothing.

* * *

A good story is told of the late Sir James Barrie who was lunching with an editor. The editor, being of the technical species and not feeling very much at home with things literary, said: "I suppose all your plays are not an immediate success, are they?" "Well, you know," replied Sir James, "some peter out and some pan out."

* * *

There has been considerable publicity given to free seating in the parks recently by the suggestion of the First Commissioner of Works that would-be philanthropists might donate seats in parks, villages and towns. To which end he has designed a new type of seat, made in oak, and more comfortable than the old-fashioned one with the cast-iron sides, which has hitherto been used. Besides being more comfortable, all the available cast iron is now needed for rebuilding the "wooden walls of England," so to speak—and when one comes to think of it, the specification for the ideal park seat must be an exacting affair. Incidentally, the little town of Lewes, in Sussex, has been made a very pleasant place in which to linger, thanks to the generosity of a much esteemed foundry owner—Mr. Every—who has given many seats which have been placed at the many viewpoints in the town and its immediate surroundings.

"Marksman."

Publication Received

Official Guide to Coventry. Compiled by James Taylor. Published by the Corporation of Coventry, Council House, Coventry. Price 6d.

The past and present are exceptionally well balanced in this artistically produced brochure. We found the chronological table of absorbing interest, whilst the case for the creation of new and extension of existing industries is attractively disclosed, much reliance being placed on the art of photography. It was a nice thought to include the portraits of the city's officials, as these are the first people with whom one makes contact when seeking information as to industrial sites.

The Commercial Production of Refined Pig-Irons for High-Duty Castings*

By G. T. LUNT

Refined pig-irons may be defined as those which are prepared by retreating blast-furnace pig-irons with the object of improving their properties, qualities and characteristics for special requirements. The actual character of the refining operations may consist of the removal of some or several objectionable constituents, or it may consist of the admixture of other desirable constituents or special treatments, depending entirely on the nature of the particular purpose for which the iron is intended. The commercial production of refined pig-irons has apparently been quite an important manufacturing process for well over a century, and in the latter half of the eighteenth century pig-irons were subjected to a refining treatment with the object of rendering them suitable for conversion into wrought or malleable iron.

In the "bloomery" or shallow hearth type furnace used in those days for the production of malleable iron, it was found that white pig-iron was more suitable for conversion, owing to its becoming pasty in melting, in which condition it would be thoroughly incorporated with the slags rich in iron oxide. In order to utilise pig-irons of grey fracture, a kind of initial treatment was developed in which they were converted into white irons. This process was carried out in a hearth type furnace with deeper walls, which was known in this country as a "finery," and the operation definitely referred to as refining.

The "finery" consisted of a rectangular hearth about 3 ft. wide, 2 ft. long, and 2¼ ft. deep. Above this hearth a chimney about 18 ft. high was usually erected. The hearth was formed of water-cooled iron blocks, and a number of tuyeres inclined downwards towards the hearth at an angle of 25 to 30 deg. were provided. The hearth was filled with coke, and layers of iron and cokes subsequently charged. Under the action of the blast on the incandescent coke the metal was melted, and was subjected to the continued action of the blast in the bottom of the hearth for a sufficient length of time, according to the extent to which it was desired to refine. The refined metal was tapped out into a shallow cast-iron mould in the form of a plate about 10 ft. long, 3 ft. wide and 2 in. thick. This refined metal or plate metal, as it was sometimes called, was broken up into small pieces for further conversion into malleable or wrought iron. In this case it is clear that the term "refined iron" was applied to the product of the "finery," which, in turn, was simply an intermediate stage between grey pig-iron, on the one hand, and malleable or wrought iron, on the other.

Development of Refining Processes

To-day, whilst there is a certain amount of refined pig-iron manufactured for use in the production of wrought iron, the majority of the refined irons are used in the iron foundry for the production of castings, particularly white-heart malleable castings and castings of high-duty character, such as are used for cylinders, rolls and other purposes where a high standard of physical and mechanical properties is required. This change in the uses of refined irons has been brought about obviously by the gradual displacement of the earlier methods of wrought iron production, firstly by the puddling processes and latterly by the Bessemer, crucible and open-hearth steelmaking processes. The developments in the manufacture of malleable castings and the improvements in the qualities and characteristics of grey cast irons have opened up other fields, and the high standard of requirements of the modern iron foundries has resulted in the development of refining processes which have considerably extended the commercial production of refined irons. It is of considerable interest to record a very early practice in iron foundries of remelting pig-iron once or twice before using it for castings. This procedure was frequently a condition of early specifications for high-grade castings, and actually became known as refining, and the product spoken of as "refined pig-iron."

Types of Irons

Refined irons as produced to-day for commercial purposes can be divided into four broad classifications.

(1) *Refined Malleable Pig-irons.*—These are for use in the production of malleable castings, principally of the whiteheart type. Such irons are essentially low in silicon content and possess fracture characteristics varying from white, through the mottled ranges to hard grey fractures. Whilst some foundries still attach a great deal of importance to the fracture characteristics, in addition to chemical composition, in refined irons for this purpose, there is a noticeable tendency towards the use of the chemical composition alone as the criterion of suitability for specific purposes. In the refineries with which the author is connected, refined malleable pig-irons, in addition to being produced to close limits of chemical composition, are produced to meet fracture requirements, and ten different fractures are recognised and produced. These, together with their analyses, are enumerated in Table I.

Table I.—*Analyses Ranges and Fractures of Malleable Pig-Irons.*

	Carbon. Per cent.	Silicon. Per cent.	Sulphur. Per cent.	Phosphorus. Per cent.	Manganese. Per cent.
Grey, Chilled grey, Grey mottled	2.90–3.20	0.90–1.40	0.06–0.10	0.07 max.	0.25–0.40
Soft mottled, Medium mottled, Hard mottled	2.90–3.20	0.70–0.95	0.06–0.10	0.07 max.	0.25–0.40
Hard hard mottled, Spotted white, Tick white	2.90–3.20	0.65–0.85	0.07–0.11	0.07 max.	0.25–0.40
White	2.90–3.20	0.55–0.75	0.07–0.12	0.07 max.	0.25–0.40
	2.90–3.20	0.35–0.60	0.09–0.15	0.07 max.	0.20–0.30

(2) *Refined Cylinder Pig-irons.*—Such irons are for use in the production of high-grade grey-iron castings. This classification covers a wide range of specifications as to chemical compositions and mechanical properties, but may be regarded as including all those irons produced to guaranteed chemical compositions, and under such conditions as ensure uniformity and regularity of composition and of physical and mechanical properties. These irons are used extensively in the production of cylinder and cylinder component castings for engines, pumps, compressors and the like, and also find use in the production of a wide variety of other types of castings where similar high standards of physical and mechanical properties are required.

(3) *Special Refined Pig-iron Qualities.*—This broad classification of special refined pig-irons includes those prepared synthetically to match both in composition and properties blast-furnace irons such as Swedish and genuine cold-blast irons. It also includes irons prepared by special processes, having special structural characteristics, irons possessing the fine graphite structure, irons possessing special chilling properties, inoculated irons, irons possessing specially high total carbon contents and irons specially free from such constituents as sulphur, arsenic and phosphorus. Over the past few years many developments have been made in refining processes for special purposes of this kind. The author had the privilege at the International Foundry Conference in Belgium last year of describing the developments in refining processes for the production of irons to match exactly genuine cold-blast irons.

(4) *Refined Alloy Pig-irons.*—This classification now covers a wide range of irons containing such elements as copper, nickel, chromium, molybdenum, tungsten, titanium and vanadium. Irons of complex alloy composition are manufactured for use either direct or in admixture with other pig-irons for the production of the wide variety of high-duty alloy cast iron specifications. The manufacture of rich alloy cast irons such as the austenitic irons, nickel-copper-chrome, and chrome-nickel alloys, for the manufacture of "Ni-Resist" and "Ni-Hard" in ingot form is a comparatively modern extension of the productions of the refineries. In this field, the economic value of the products in a great measure lies in the guaranteed accuracy and uniformity of the chemical composition rendered possible by the use of carefully-controlled refining methods.

Variations in Production Methods

In many respects modern methods for the commercial production of refined pig-irons vary considerably. It will be appreciated that the preparation of many of the grades of iron referred to in the various classifications involves the application of various treatments to the molten metal, and the various methods differ essentially in the means adopted for obtaining the molten metal and the facilities rendered available for the treatment of the metal in the molten state. The simplest and the oldest of the methods in commercial use to-day is the direct use of the cupola-type furnace, in which the required result is obtained by melting together suitable blast-furnace pig-irons and, if necessary, steel scrap. In this method reliance is placed on the metal mixture and the changes which take place, and can be brought about by skilled control in melting to obtain the desired result. The use of the cupola alone is limited in the facilities it affords for the treatment of the metal in the molten condition. These limitations can be alleviated somewhat by the use of a receiver. An extension of this method is the use of duplex processes in which the initial melting is carried out in the cupola and the molten metal collected either in an oil-fired receiver or furnace, electric furnace or pulverised-fuel furnace.

Duplex processes of this type allow of facilities for the treatment of the metal in the molten condition and with skilled operation of the cupola furnaces, facilities for obtaining a wide variety of results are possible. Modern refining plants operating on duplex systems employ specially-designed cupola furnaces, built for heavy-duty work and operation over long melting periods, frequently embodying water-cooled tuyeres and even water-cooled lining blocks in the bosh of the furnace. Considerable attention is paid to

* Paper presented to the International Foundry Congress held in Paris. The author is managing director of Bradley & Foster, Limited.

the design of the lining, both as regards shape and thickness, to deal effectively with the varying nature of the metallic portion of the burdens. Scientific methods of controlling the air supply are of importance, and these involve not only the use of suitable controlling devices over the air supply, but also suitable tuyere design. In the plant with which the author is associated oil firing is adopted in the duplex furnace. After-treatment of the molten metal is carried out in this oil-fired receiver, and one of the principal treatments so applied is the now well-known degasification process, which was described in the author's Paper given before the International Conference held last year in Belgium.

Rotary-Furnace Melting

Melting in rotary furnaces both oil-fired and fired by powdered coal is one of the recent methods adopted in the production of refined irons. Powdered coal firing is adopted principally, and such furnaces enable superheating and slags and ensures the uniform and thorough incorporation of any alloy additions. Such alloy additions can be made readily in duplex processes, and they have undoubtedly played a very important part in the modern developments in the production of alloy pig-irons.

For the most part, refined pig-irons are cast in sand moulds, but there is a rapidly growing tendency towards the adoption of machine casting, using metal moulds. This has been adopted already in so far as many of the refined alloy pig-irons are concerned. The use of machine casting induces a close fracture even with pig-irons having a naturally open fracture, and tends to mask any intrinsic tendencies to open or close grain in the iron. For this reason the foundries have been hitherto somewhat chary in the adoption of machine-cast pig-irons. There are, of course, several advantages in machine-cast pig-irons. The freedom from sand, convenient size and close fracture should appeal to all foundrymen aiming at close, clean, strong castings, and general castings over the past ten years. More recent investigations are tending to show the additional importance of the structural character, and the suggestion that to obtain sound close-grained fine structures in the castings one must charge into the cupola sound close-grained fine-structured pig-iron has almost become a metallurgical precept.

Refining processes enable the desired compositions and these initially fine structures to be obtained, and their use either exclusively or in admixture with blast-furnace pig-irons in foundry mixtures has now become a recognised method of producing general castings not only possessing a high standard of mechanical and physical properties, but also castings free from unsoundness and internal defects.

Details of the use of refined irons in general foundry mixtures have been published frequently. An excellent example is to be found in the Paper by J. L. Francis.* These recommendations are reproduced in tabulated form in Table II and disclose a system of metal mixing

Table II.—*Correct Metal Mixing Practice.* (*J. L. Francis.*)

Cupola mixture. Per cent.	Calculated chemical composition. Per cent.					Physical tests.			Suitable for casting.
	T.C.	Si.	Mn.	S.	P.	Tensile. Tons per sq. in.	Transverse. Tons per sq. in.	Specification conformed to.	
15 Scotch 15 Refined 40 Returned scrap 20 Foreign scrap 10 Steel scrap	3.25	1.70	0.70	0.08	0.65	14.0	25.5	B.S.I. No. 321/28 S. Bar Grade A. Also British Admiralty Grades 2	Flywheels, rotors, couplings, crankcases and medium sectional work not required to withstand high pressure.
25 Foundry 25 Refined 40 Returned scrap 10 Steel scrap	3.20	1.65	1.0	0.10	0.55	15.0	26.5	Test-bar sizes as above	Castings similar to above needing slightly tighter metal giving greater wear and pressure resistance.
50 Refined 40 Returned scrap 10 Steel scrap	3.0	1.4	0.95	0.10	0.45	16.0	28.0	Test-bar sizes as above	Turbine casings, cylinder liners, covers and heads, pistons, gearcases, valve sleeves; castings of heavy section to withstand heavy wear and pressure conditions.
50 Refined 40 Returned scrap 10 Steel scrap	3.0	1.15	1.0	0.10	0.45	17.0 with Ni 18.0+	30.0 with Ni 32.0+	For special high-test requirements.	Castings as above. Valves and work having to conform to special service conditions.

treatment of the molten metal to a considerable extent to be carried out in the one furnace.

Very similar in character is the use of the open-hearth furnace of the regenerative type and also the simple reverberatory type. A special feature of these latter is the facility they offer of melting down material in large unit masses, such as, for example, scrap rolls and ingot moulds. The Bessemer or Tropenas type of converter is also adapted for the production of refined irons, and in this case changes in composition are brought about by the familiar Bessemerising actions and after-treatment of the molten metal carried out in the converter body itself and also in the ladle.

Advantages of Duplex Processes

From the point of view of facilities for carrying out the many different refining operations to meet the large variety of modern specifications, probably duplex processes are the more satisfactory. By their use the molten metal can be superheated where this method is required for the production of refined iron having the structural characteristics associated with superheating. They afford ample facilities for treatment of the metal with special slags for the removal of sulphur and arsenic, as, for example, the use of soda-ash slags. Duplex processes can be adapted to permit of the use of degasification processes and its variations, such as the vibration processes. The Bradley patent degasification process used in the works with which the author is connected is, for example, carried out under conditions of superheating and in conjunction with the use of refining slags. In this manner, in addition to securing the degasification effect, it assists in the refining action of the in the case of refined pig-irons made under controlled conditions to guaranteed compositions and mechanical properties, the modification of the fracture due to machine casting is surely of less significance. In connection with this matter, it is of some general interest to recall the fact that the earliest refined pig-irons in Great Britain were cast into metal moulds in the form of plates. In this respect they were similar to the product of the modern pig-casting machine.

Application of Refined Irons

Apart from their use in the production of malleable castings and their application to the production of such special castings as chilled and grain rolls, and other castings demanding special qualities and attributes in the pig-iron, refined irons are finding increased use in the production of general castings. They place at the disposal of the ironfounder means for the production of high-duty castings to meet the more exacting requirements of modern specifications, and, what is perhaps more important, they assist the ironfounder in the production of sound castings free from internal defects. Refined pig-irons for such general purposes fall within the second classification of refined cylinder pig-irons, and apart from any inherent qualities which they possess their usefulness depends very largely upon their fine-grained, fine-graphite structures, and their lower total carbon contents in comparison with straight blast-furnace irons. The realisation of the effect of chemical composition, particularly as regards total carbon and phosphorus contents, on soundness, freedom from shrinkage and porosity, may be regarded as one of the most outstanding improvements in the metallurgy of cast iron in so far as it affects the production of practice which may be safely employed without any departure from standard grey iron practice. In view of the results obtainable from these mixtures, the fact that ordinary standard foundry practice can be adhered to is regarded as a definite advantage.

This short description of the commercial production of refined pig-irons refers, of course, to the practice which has developed in Great Britain. Refining processes and refined pig-irons are of first-rate importance in the production of high-duty iron castings, and there can be no doubt that the rapid growth in the development of such cast irons during recent years has been assisted in a very large measure by refined and refined alloy pig-irons.

* "Iron and Steel Industry," November, 1936.

Canadian Iron and Steel Production

For the first half of 1937 the total Canadian production of pig-iron amounted to 423,944 tons, an increase of 25 per cent. over the 340,335 tons reported for the first six months of 1936, which in turn was 31 per cent. over the corresponding period of 1935. The output of ferro-alloys for the six months totalled 30,856 tons, against 30,550 tons and 22,192 tons during the corresponding periods of 1936 and 1935 respectively. The production of steel ingots and direct steel castings for the half year was 713,177 tons, as against 578,700 tons and 388,163 tons reported for the first half of 1936 and 1935 respectively. During June new business increased and prices held firm. Many steel mills were engaged in filling rail orders placed earlier in the year. Deliveries were generally four to six weeks behind schedule time. The volume of "backlogs" is at the highest level in several years, and with the active current demand is considered ample to maintain operation at present rates till the close of the year.

A New Rapid Analytical Method

THE USE OF THE SPECTROSCOPE

Writing in "The Iron Age," under the caption, "25 Determinations on Cast Iron in 25 Minutes," MR. FRANK J. OLIVER, Associate Editor of that journal, discloses that America is using a unique method of compositional control. Below is an extended abstract of Mr. Oliver's article.

Spectrographic analysis of metals is not new. It has been used as a qualitative check for years, and as a research laboratory technique it has been known for over a hundred years. Any handbook of physics and chemistry gives tables of wave lengths of various spectra of all the common elements. For iron alone, there are hundreds of known wave lengths. The method is a regular tool of astronomers in identifying the elements in distant planets. Only in the last year, however, have the chemico-physical phenomena of the variations in intensity of light emitted by incandescent vapours of metallic elements been applied in the ferrous foundry industry as a quantitative measure. To make this possible required the practical vision of a foundry executive and the co-operation of a university research laboratory in putting a complex theory into practice. Mr. Ira A. Wyant, secretary of the Campbell, Wyant & Cannon Foundry Company, had the vision, and Dr. H. B. Vincent and Prof. R. A. Sawyer, both of the University of Michigan, performed the commercial development work at Ann Arbor. Mr. A. M. Sampson, spectrographic engineer of the foundry, was constantly in communication with the shop and the university, lending an engineer's viewpoint on the mechanical details and eventually taking charge of the laboratory installed at Muskegon.

In the spectrographic method, a high-frequency spark is struck between two small electrodes of the material being examined, and the light emitted therefrom is passed through the slit of a spectrograph. This instrument contains in its optical system a prism that spreads out the band of diffracted light so that it can be photographed as vertical black lines of varying degrees of density. Each element present in the sample has a characteristic line or lines which can readily be identified. The density of these lines varies according to the amount of the element present, and the variations can be measured by means of an instrument, known as a densitometer. Through calibration charts and special scales the density can be compared with other rigidly standardised spectrographs and converted directly to a percentage of the element present. Such calibration charts and scales must first be made up from samples analysed in the chemical laboratory.

Laboratory Requirements

The requirements of a spectrographic laboratory are therefore:—(1) The necessary electrical apparatus for producing the spark; (2) the spectroscope (highest cost unit); (3) photographic darkroom with suitable apparatus; and (4) the densitometer, with calculation table alongside. Altogether, exclusive of the building, the investment in such equipment is approximately £1,600.

The spectrographic technique has its practical limitations, and as applied in the Muskegon foundry, it is used for determining the percentage of silicon, manganese, chromium, nickel, copper and molybdenum. Carbon determinations as yet have to be made by chemical analysis in the usual manner, as do sulphur and phosphorus checks, which are made only in a percentage of the heats. It might be explained that copper-silicon steel brake-drums are a regular production line and heats are checked every 15 min. In addition, motor vehicle cylinder blocks and heads, camshafts and cylinder liners, chiefly of high alloy material, are regularly poured. Much of the metal is duplexed in the electric furnace, and the cupola iron is mixed with Bessemer steel to make the drums. Samples of iron are obtained from the transfer ladles after the alloy additions have been made.

The electrical arrangement for producing the spark is shown in the chart, Fig. 1. Primary current is at 220 volts and 60 cycles. The oil-immersed transformer steps up the voltage to 40,000 and the four-pole interrupter (driven by synchronous motor) with suitable condensers produces a discharge oscillation of about 300 kilocycles at the spark gap. About 1½ kw. of energy is consumed. The electrodes are 1 in. long by ⅛ in. in diameter, and are cast four at a time in a permanent mould with plenty of metal in the common riser. This mould is hinged for opening and is poured from a small hand ladle used to dip the iron out of the transfer ladles. Fins are trimmed off the electrodes by the same pair of pliers that is used to break them off the

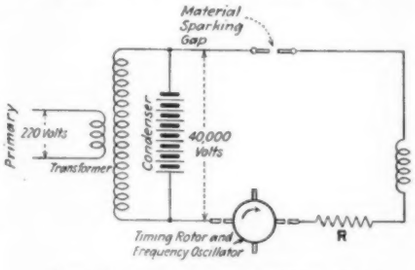

FIG. 1.—ELECTRICAL CIRCUIT FOR PRODUCING THE SPARK.

riser. Only two out of the four stubs are necessary for electrodes, and these are slipped in a holder that gives the correct spark gap when the electrodes are clipped in the machine. Experience has shown that a 50-sec. exposure is best suited for the plates used, and is sufficient to give reliable results.

The spectrograph proper is a Littrow type, made by Bausch & Lomb Optical Company, of 1,820 mm. nominal focal length. The plate holder has been revamped to take a plate 4 by 11½ in. instead of a 10-in. plate as originally designed. Only the light in the ultra-violet range (0.224 to 0.295 microns wave length) is focused on the plate, so that all the optical elements must be quartz. The bilateral slit has a fairly large opening (70 microns) to get a wide enough line to work the densitometer and its galvanometer. Spark and slit are about 4 ft. apart. The plate holder is adjustable so as to expose a strip ¼ in. high at a time. In this manner as many as nine spectrographs can be recorded on a single plate, although four to six exposures are usually averaged.

Two men operate the equipment. One sets up the electrodes and starts the action, the second being in the adjoining spectrograph room, where he times the exposure and cuts the circuits, then shifts the plate for the next shot.

Processing the Spectrographic Plates

These spectrographic plates may be described as high-contrast, fine-grain plates. Such plates are inherently slow, but high exposure speed is not desired in this phase of the process. What is much more essential is the time of processing the plates, which should be reduced to a minimum. According to the batch and make, time of development may vary from 45 secs. to 2½ min.; fixing in hypo., from 1 to 4 min., and the length of wash varies accordingly from 1 to 4 min. In between developing and fixing, there is a 30-sec. rinse in a chrome-alum hardening bath, and it takes only from 1 to 2 min. to dry over an electric heating box with fan assisting in carrying away the vapour. A standard Eastman hydroquinine developer (Formula D-19) is usually employed, and developing, hardening and fixing trays are all mechanically rocked by an electric motor and crank mechanism. Because of its lack of sensitivity to red, the plate may be loaded and developed under fairly bright red ceiling lights. The plate is rinsed and sponged off with distilled water so as to leave no mineral deposits that might affect the density. Incidentally, the dryer is home made, and consists of some resistance wire, such as is found in a toaster, strung along the bottom of a shallow box, the cover of which is the plate to be dried. An ordinary fan blows across it and prevents the plate from scorching, besides hastening evaporation. Using the fastest processing plate available, the total time for darkroom work is 5 to 6 min.

Analysis of Spectrum Lines

Analysis of the spectrum lines is made on the densitometer in an adjoining room, which is in darkness except for the tube lamp over the computing table. The same two men handle this phase of the technique, one reading the densitometer, the other computing and recording. This densitometer is an instrument with a light source that is projected through the plate in a narrow beam. By means of mirrors, the light thus screened by the spectrum line is projected on a photoelectric cell which is connected to a galvanometer at the far side of the room. From the same light source a small beam is emitted from the back side on to the galvanometer mirror and is reflected on a suitable scale in the densitometer proper. This instrument has also been revamped. The frame holding the plate has been rebuilt so as to make the location of the spectrum lines more positive and more accurate. There is an up-and-down movement to bring individual spectrographs into position for analysis, and the cross movement has three speeds: a friction slide for fast manual adjustment, a rack movement for rough positioning and a screw for slow motion of a spectrum line across the field of light. The galvanometer damping has been increased to give a period of 2 secs. (rather than 7 secs.). The slow motion gives the galvanometer time to build up to maximum reading. Readings of a particular element are always relative to an adjacent iron line, of which there are many since the latter makes up about 95 per cent. of the metal analysed.

Because of the variation in emulsions and in time of development, every plate must be calibrated before readings on elements can be taken. The densitometer itself also varies, due to changes in the light source as it ages, dust on the condenser lenses and the like. This calibration is the work of a minute and is done by plotting a typical sensitivity curve. To explain this process, however, it is necessary to refer back to the original calibration of the spectrometer and densitometer by the stepped diaphragm method. This method is covered by patents taken out by Dr. Wolfe and Prof. Duffendack at the University of Michigan. In calibrating a plate by the method indicated, light from a carefully controlled lamp is passed through the diaphragm and recorded photographically as a band on the plate. The slit has stepped sections, each of which varies in width in the proportion of 1.5 raised to the 0, 1, 2, 3, 4, 5, etc., power. The figure 1.5 is empirical and was determined by experiment. Thus, the relative slit widths are (1.5 deg.), 1.5, 2.25, 3.38, 5.07, 7.61, etc. By calling 1.5 the base of a logarithmic system, we have as the logarithm of the slit width simply 0, 1, 2, 3, 4, 5, etc. It was a simple matter to find iron lines in the

spectrograph corresponding in depth of shade to the stepped densities produced in the experimental plates by the diaphragm. When the densitometer readings are plotted as ordinates and the logarithm slit widths (exposure) as abscissæ, the shape of the curve drawn between the points is practically straight for the main portion, with the ends falling off, somewhat like a half loop of a hysteresis curve. This calibration curve is plotted in pencil on millimetric graph papers.

All analytical readings are referred to this curve. To obtain a reading on silicon, for example, the nearest iron spectrum line is first read for maximum galvanometer deflection, and the point on the curve corresponding to this reading becomes momentarily the base line for silicon determination. By means of a transparent slider with ruled vertical line, the zero point of a conversion scale is brought in line with this point. The silicon line is then read and the percentage of the element present is read directly from the scale below the slider hair line which has been moved to the point on the calibration curve corresponding to its densitometer readings. For each element, an empirical scale has been worked out, reading directly in per cent. These scales were built up by check through chemical analysis. Once the calibration curve is made, the percentages for the various elements can be read off as fast as the densitometer readings can be called off in pairs. Average accuracy of results is within $\pm$ 2 or 3 per cent. of the amount present, with an occasional maximum variation of $\pm$ 5 per cent. of the amount present.

Conditions Held Constant

Conditions throughout must be maintained constant to get reproducible results. A voltage regulator is necessary to keep the primary potential constant on the sparking machine, because there is an electric furnace on the same line melting cold iron and producing a very irregular line load. A compressed-air jet is blown across the spark to clear gases as rapidly as they are formed. Furthermore, the electrodes are pointed in a small bench grinder to a 5-deg. flat angle, giving a slightly conical shape and tending to centre the spark.

Whether a spark or arc should be used is still a debatable question, as was brought out at a conference on spectroscopy held last year at the Massachusetts Institute of Technology. Initial use of the arc method proved unsatisfactory at the Campbell, Wyant & Cannon foundry, and the spark method has been much more satisfactory here. Its temperature of 10-15,000 deg. C. raises the atoms to a high level of excitation, and maintains a very uniform condition. For purely qualitative analyses, the low-voltage arc with its 5,000-deg. C. temperature is preferred, since it will show up more elements when present in small amounts.

There is a considerable saving in time and in apparatus by this method. Allowing for time to let a sample cool in a sand mould and to drill the chips, it requires at least 30 min. to run a silicon determination on a single heat. To determine copper content would require a large amount of plating-out equipment, since these checks are made three to four times an hour. While the silicon is being determined by chemical analysis, an average of five elements in five different samples can be determined quantitatively by the spectrograph, including the copper content.

Carbon content runs in the Campbell, Wyant and Cannon laboratory are made by a fast technique, so that the results are available simultaneously with the spectrographic analysis. Under the present system it is readily possible to have the analyses of five ladles of different metal back in the melter's hands within a half-hour.

Upon first sight, the technique seems ultra-scientific and out of place in a jobbing foundry.

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(*Concluded from previous column.*)

Yet when reduced to a routine basis, it requires only a normal amount of skill and intelligence.

The plates are filed by days of the month in an octavo size steel file. Wrapped around each plate is a slip of paper giving the order of analysis, identifying the furnace from which each heat was poured, and the product, such as cylinder liners, as well as the sequence of spectrographs on the plate. The time of day is also recorded, as test samples are generally run hourly. The calibration charts are destroyed, since the light source in the densitometer is not a constant, as has been explained. Besides, it is a simple matter to calibrate the plate again if necessary. After three months, the plates are destroyed, but could be stored in boxes if so desired. Electrodes are kept only for a day, then scrapped. Complete analyses reports are returned to the melters and are filed elsewhere, as well as a running report of analyses of samples from hour to hour.

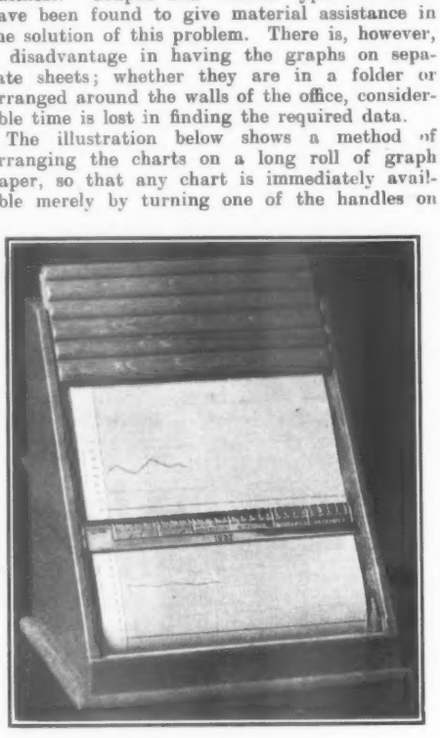
Thus, it is evident that the spectrographic technique is not only wholly practical, but extremely fast. By it a foundry is able to get closer than ever before to that ideal point of knowing what is in the ladle before a mould is poured.

A Graph Cabinet

By W. Corbett.

The present-day executive finds an ever-increasing necessity for concise presentation of the vital information he requires to direct his business. Graphs and various types of charts have been found to give material assistance in the solution of this problem. There is, however, a disadvantage in having the graphs on separate sheets; whether they are in a folder or arranged around the walls of the office, considerable time is lost in finding the required data.

The illustration below shows a method of arranging the charts on a long roll of graph paper, so that any chart is immediately available merely by turning one of the handles on



The Graph Cabinet.

the side of the cabinet. If the cabinet has a permanent position on the executive's desk, it will be found that the information detailed upon the charts is much more frequently used than if a search had to be made through one or more folders before the required chart was found.

Uses

The type of chart which may be drawn on this roll of paper is not limited to simple line charts; "Z" charts, bar charts (horizontal and vertical) can all be drawn with equal ease provided suitable scales are chosen. Modern cost accounting methods aim at providing the executive with as many details as possible regarding the expenses over which he has control. Many people having a number of sections under their control will find the weekly review of their control books to be a rather lengthy business, and the executive will find his task facilitated if the information presented in the control books is arranged in the form of simple line charts by one of his assistants. He will then be able to see at a glance the trend of his expenses, and the reasons for any excessive increases can be investigated, and checked if necessary. Line or bar charts showing cost of production may also be included in the information shown on the roll.

Sales is another important feature which can be recorded in this manner. The information available regarding sales or output may be analysed as required and a simple line—or better still a "Z"—chart can be drawn from each section. This will show at a glance the types of products which are selling well, the activities of the salesmen, the trend of sales in different districts, etc. In any trade where an analysis of the product is made, *e.g.*, the foundry, the results may be plotted in the form of a simple line chart, and any variance outside the accepted limits can be immediately seen and checked.

These are only a few of the many types of graphs and charts which could be shown in the manner illustrated. Each executive will naturally prefer his own particular type of chart, but the fact remains that practically every type can be gathered together on this roll and any of them can be quickly found by consulting a small index and giving a few turns to one of the handles until the graph required is identified by its number when it appears at the front of the cabinet.

Construction

The principle of the graph cabinet is similar to the destination indicator used on tramcars or motor 'buses, *i.e.*, a roll of paper runs on two rollers. This means, however, that at the end of the period a new roll will have to be inserted and reference to old charts will be more difficult when they are removed from the cabinet. To overcome this difficulty two large rollers, on which a much longer length of paper can be stored, may be used. If this is done, several periods (possibly five or ten years) can be recorded on the same roll of paper, and reference to past results will be greatly facilitated. Another advantage obtained by utilising this method is that the two large rollers may be geared together; this ensures that the paper is kept at an even tension and only one handle is required to operate the rollers. When this method is employed, the rollers at the top and bottom of the cabinet are merely used as carrier rollers. Between these two rollers there is a base board which provides a firm background against which the graph paper rests whilst entries are being made.

The length of the rollers depends on the scale chosen; in the illustration the paper used is mm. squared, and the width is such that one roll will last for 26 weeks. If the period scale is common to all the graphs or to a number of them, a plated strip of metal with the week or month endings engraved upon it may be fastened across the paper. If it is accurately set, the strip will serve the dual purpose of defining the scale and acting as a paper guide. When the paper has been fastened to the rollers, a start can be made on the charts.

If the information contained on the charts is of a private nature, a roll shutter arrangement can be made to slide down the front of the cabinet and lock at the bottom; alternatively, a sliding glass window may be preferred.

Malleable Iron Melting Practice—Retrospective and Prospective*

By H. H. SHEPHERD

Introduction

In presenting this Paper on behalf of the Institute of British Foundrymen, the author wishes to state that he has several reasons for selecting a review of some phases of the manufacture of malleable iron castings as the thesis. One of the reasons is that the author's experience in connection with the production of whiteheart and blackheart malleable cast iron extends over quite a number of years, and during this period of time he has always been impressed by the comparative paucity of correlated information relating to malleable cast iron melting practice, especially in regard to its developments.

This is particularly true in respect of European information, and although there has been a considerable number of excellent Papers published by one or two French, German and English authorities, most of these deal with particular phases of the industry. Iaroyer (French) and Stotz (German) have, within recent years, published text-books dealing fairly thoroughly with the subject, but there is no modern book on malleable iron by an English authority. When one wishes to obtain correlated information relating to blackheart or American malleable cast iron, one can only consult a book published 15 or more years ago, namely, Schwartz' well-known treatise "American Malleable Cast Iron."

A third factor which influenced the author in the choice of this subject is that he believes that the following sentence appertaining to malleable cast iron still applies, although it was published in an English book more than 75 years ago:—"It occurs to us that the application of iron thus treated has not as yet nearly realised the importance to which it is entitled." *Vide* "The Useful Metals and Their Alloys," published in 1861.

The aim of the author will, therefore, be to present some correlated data relating to some developments in connection with malleable cast iron, particularly melting practice, with the hope that, though he may add little or nothing for which he can claim originality, his attempt will, at least, stimulate further interest in a branch of industry which abounds with metallurgical interest and commercial possibilities. This latter statement may appear too confident to many engineers and even metallurgists who are not conversant with the physical characteristics and reliability of correctly produced modern malleable cast iron, and also with the very many applications in modern engineering for which various types of malleable iron castings are particularly suitable.

Up to comparatively recent times, secrecy and conservatism, coupled with lack of metallurgical knowledge, were particular weaknesses of the malleable iron industry and had, in consequence, a restraining influence on the production of malleable castings in Europe. Lack of knowledge meant rule-of-thumb methods, and this resulted in a product which invariably was unreliable, hence, the engineer's experience with malleable castings was not a happy one, and there is some justification for that almost inherent suspicion of many engineers in regard to this product.

International Statistics

This suspicion, linked with conservatism on the part of the European engineer, is still reflected in the malleable castings output of Europe compared to that of America, as the following figures clearly show. Whilst these figures are not quoted as official, or as being definitely correct, they do present an approximate idea of relative tonnages per annum:—

U.S.A.	560,000 tons.	
Germany	85,000 ,,	
France	50,000 ,,	(?)
Great Britain	60,000 ,,	

It is a significant fact that the largest output of malleable castings, both of the U.S.A. and England, is of those made in malleable cast iron to which actual scientific control was first applied, namely, malleable iron made by the blackheart process.

There is no doubt that the secret of successful manufacture of either whiteheart or blackheart malleable lies in the constant application of scientific control. Lack of such control methods in the whiteheart plants of years ago resulted in a product which belittled this industry in the eyes of the engineer. Even to-day the very crude methods of many such works serve to support the lack of confidence expressed by many engineers. On the other hand, there is proof that whiteheart malleable produced under scientific principles of control commands a good market, and the most prosperous whiteheart foundries of Europe are those which appreciate the importance of this control.

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Development Reviewed

If one reviews the development of the malleable castings industry during the past twenty years, it is soon realised that the greatest progress has been in connection with blackheart malleable, and though a number of European investigators have made very important additions to the knowledge of this type of malleable iron, in general, most of the information and developments have come from America.

The author would hasten to add that malleable iron made by the blackheart process for many years was far from reliable; in fact, uniformity of the blackheart malleable product is a comparatively recent development, dating from the time when it was recognised commercially that packing in oxidising materials was neither essential nor advisable in the production of good quality blackheart material.

How often in the past has one heard the expression, "The strength of malleable iron lies in the skin of the metal only"? It could be truly applied to much of the early white and blackheart material which often contained fair amounts of fine primary carbon or graphite which was not easily seen in the castings in the "as-cast" or unannealed condition.

Schwartz,[1] referring to the above quotation, states:—"This thought persisted from the days when malleable iron was made 'malleable' by decarburisation only, as is the case with the so-called 'whiteheart' product of Europe." It is well known that the physical properties of whiteheart malleable do vary appreciably with the degree of decarburisation, and since the decarburisation process is essentially a function of time, temperature and sectional thickness, the standard of uniformity of properties of whiteheart malleable iron can never be anything approaching that of malleable iron made by the blackheart process.

Sectional Limitations

It is these variations of time, temperature and section which makes it somewhat difficult to fix standard specifications covering physical test requirements of whiteheart malleable, and, according to H. Field[2] and others, the limit of section is placed at 0.75 in., beyond which it is not commercially practicable to produce true whiteheart castings. It is equally well known that, provided castings are free from primary carbon, there is no sectional limit to castings which can be produced in genuine blackheart malleable, and, provided that the castings be raised to the required temperature throughout, the annealed structure will be the same in kind throughout and vary only in degree from surface to centre.

One cannot, however, entirely dismiss the quotation made above with reference to "strength . . . in the skin" when considering blackheart material. The name in itself was derived from the fact that originally the annealed product possessed a fracture having a steely decarburised edge and a black interior or heart. The extent of decarburisation was not nearly so much as is the case with whiteheart metal, because the packing material used for the former process was a much weaker oxidising material and, further, the composition of the metal was such as to bring about graphitisation in the interior before the decarburising action had penetrated far. Nevertheless, the decarburisation which did take place, and which varied extensively according to the annealing practices and metal composition of different manufacturers, had an influence on the physical properties of the test-bars. In other words, a blackheart malleable tensile test-bar which possesses an appreciable decarburised skin will yield a higher maximum stress value, but lower elongation than a similar sized bar which has been made in accordance with modern blackheart practice, the decarburisation of which would be almost negligible.

It should, however, be pointed out that the extent of the influence of decarburisation upon the physical properties depends on the carbon content of the original metal, and the higher the carbon, the greater is the effect, and *vice versa*. The earlier blackheart malleable, being higher in carbon content than the product of the last twenty years, was undoubtedly more affected by decarburisation.

Correctly produced modern blackheart malleable possesses an all-black silk-like fracture when broken in normal ways; further, properly made test-bars of this material will yield the same physical test values if tested after machining off the skin as when tested without machining; in fact, the tendency is for the machined bars to give somewhat higher values as machining removes some of the surface imperfections.

Competition from High-Duty Cast Iron

Reverting to considerations of the general developments of malleable iron and its commercial possibilities, the author would repeat what he has stated elsewhere.[3] "Another factor which emerges from a study of this progress is that there is a narrowing of the gap which exists between the physical properties of good

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* Paper presented on behalf of the Institute of British Foundrymen to the last International Foundry Congress held in Paris.

quality malleable iron and the modern high-strength cast irons. Now this 'narrowing' can work in two apparently opposite directions; it can mean the encroachment of the grey-iron castings into the malleable castings market; it can also result in the high-strength grey-iron castings market being encroached upon, particularly alloy cast irons, by the malleable industry. The progressive malleable manufacturer has strengthened himself against the first possibility, by methods such as indicated above, which will be considered in detail later, and he is making every endeavour to bring about the second possibility.

"The malleable industry has also made inroads on the forging and steel castings markets, but again these inroads have been made mainly by manufacturers of blackheart malleable. There seems, however, no reason why the whiteheart industry should not benefit to an equal extent if it is prepared to add its quota to the support of individual or collective research." The author therefore feels that his expressed confidence in the future commercial possibilities of malleable cast iron is quite justified.

In closing these introductory remarks, attention is drawn to the international growth of output of blackheart malleable cast iron. Since the Great War a number of countries who previously produced little or none now have a number of works producing this material. For example, according to Stotz[1] it was not until after the war that Germany began to produce blackheart malleable, but by 1929 there were 16 foundries manufacturing approximately 10,000 tons (total) per annum, and whilst later production figures are not available, there is no doubt that output has materially increased.

Definition of Malleable Cast Iron

Considerable controversy has arisen from time to time among official bodies and others as to the correct nomenclature relating to this material. On several occasions it engaged the attention of the early International Association for Testing Materials, and in 1906 the following definition was finally laid down, although according to report at the time, the Committee responsible does not appear to have been entirely unanimous about it:—"Malleable Cast Iron—Iron which when first made is cast in the condition of cast iron, and is made malleable by subsequent treatment without fusion." This definition conveys no idea as to the type of iron the metal is, in the "as-cast" condition, nor of the character of the "subsequent" treatment. Further, though the A.S.T.M. put forward some tentative definitions in 1927 relating to "annealing," "malleablising" and "graphitising," so far as the author is aware there has been no further official designation given to malleable cast iron. In consequence, the following is offered for consideration:—Malleable Cast Iron—Iron which when first made is cast in the condition of grey cast iron, but is white in fracture, and is made malleable or ductile by subsequent heat-treatment involving removal of, or conversion of, the carbon, according to the type of material required.

History

In writing a Paper of this kind the author feels that the subject would be incomplete if no reference was made to the history of an industry which dates back for more than 200 years. Further, one can rarely think of malleable cast iron as a subject, without subconsciously, at least, if not consciously, thinking of that distinguished French savant, Réamur. Réamur did not claim originality for the process of manufacturing malleable castings, in fact, he pointed out that the secret was one which had been found and lost probably many years before his experiments. However, there is no doubt that his memoirs, published in 1722 under the title "L'art d'adoucer le fer fondu," formed the first scientific treatise on the subject and can truly be regarded as the foundation stone of knowledge upon which an important and world-wide industry has become established.

It is regretted that time prevents detailed consideration of Réaumur's classic treatise, for it reveals an extensive knowledge of the subject, even when examined in the light of modern knowledge. For example, the importance of time and temperature in annealing, the influence of air, packing, etc., on scaling of the castings, were all considered. Réaumur apparently favoured the use of bone ash for packing, after experiments with many different substances, including oxide of iron, about which he made favourable observations. It should be noted that had he been using pig-iron of suitable composition which would have graphitised instead of decarburised, he might also have earned for himself the title of "Father of the two sons of the malleable iron industry—whiteheart and blackheart."

The next important step in the history of the alloy took place at Dronfield, where Samuel Lucas, in 1760, founded a works for the making of malleable castings. This establishment is still in existence and the company, now Edward Lucas & Company, are actively engaged in the malleable industry, the business having been passed down from generation to generation. In 1804 Lucas obtained a British patent for making whiteheart malleable iron castings by heating white iron castings in conjunction with iron ore. As a result of the growth of this industry, material which was previously regarded as almost unsaleable, that is, white and mottled hematite pig-iron, was in good demand.

The history of blackheart malleable is very much interlinked with that of its earlier counterpart, but as one always associates Réaumur with whiteheart malleable, so Boyden must be associated with American or blackheart malleable. Boyden was a native of Bilston, Staffordshire, who emigrated to America, and in 1820 started an iron foundry in Newark, New Jersey. It should be clearly understood that Boyden was not, in the strict sense, a scientist like Réaumur, he was, as Schwartz[2] stated, "A manufacturer rather than a scientist," who was interested in malleable castings, and who set out to make whiteheart malleable cast iron in the U.S.A.

Boyden's discovery of blackheart or American malleable was accidental, being brought about by the fact that iron which he attempted to make whiteheart malleable from, was lower in sulphur and higher in manganese than those used in Europe and, in consequence, he obtained, after annealing, metal which graphitised throughout rather than decarburised. According to Boyden's diary, he seems at first to have been very disappointed at not being able to produce whiteheart malleable, but the physical properties of the material he found that he could successfully make were such that he ventured into the business of selling castings made from it. Thus, a new industry—that of the manufacture of American or blackheart malleable cast iron—was born.

Although the process of graphitisation was discovered by Boyden, he did not understand the necessary reactions, in fact, he still thought that decarburisation was essential, and he and others stressed the importance of using certain types of oxidising packing materials. It was left to Forquignon in 1881 to show, as the result of research work dealing with the manufacture and properties of malleable cast iron, that provided the metal was of suitable composition, it could be malleablised successfully in a non-oxidising packing. However, as stated earlier, packing in material which will not decarburise is modern so far as commercial practice is concerned, and even to-day many manufacturers use moderately powerful oxidising packings. Such material is not so uniform in its physical characteristics as that produced under methods and control which aim at preventing decarburisation or reducing it to an absolute minimum.

RAW MATERIALS

Sand

One of the most important materials in a foundry is sand. Its properties and vagaries never worried the early malleable castings founder to any extent, because the moulders' "art" or skill tended to overcome these vagaries. This skill remained unchallenged until some 20 years ago when a few investigators set to work to examine very closely the many characteristics of all types of sand and to develop methods of control.

The first real authoritative methods of control were those devised by the Moulding Sand Research Committee of the American Foundryman's Association. Over a period of years these methods have been improved upon and others added and their status is now internationally recognised. In England much very valuable work has also been carried out by the British Cast Iron Research Association and by the Sands Sub-Committee of the Institute of British Foundrymen.

The rapid advent of the mechanised foundry has compelled closer study of sand conditions and requirements, and the progress of our knowledge of sand technique follows almost in sequence the progress of foundry technique. The far-reaching importance of sand control has been repeatedly stressed by progressive foundrymen, etc., the world over, and it is rapidly being recognised that it should be regarded as important as control of metal composition, if the production of good castings is to be assured.

This is particularly emphasised in connection with the founding of malleable castings, for the short freezing range of white cast iron necessitates very careful attention to the condition of moulding and core sands. They must permit rapid escape of gases coming from the mould, the metal and from the burning core binders, etc., in other words, both moulding and core sands must possess fairly high permeabilities, consistent with a grain fineness which will result in a good surface finish to the castings. The latter is very largely controlled by the uniformity of grain size. Further, the sands must possess good refractory properties for, as is well known, white iron of composition suitable for malleable castings is somewhat similar to steel in its searching action on the sand. Bonding properties must be satisfactory and at the same time high "dry" strengths must be avoided or cracked castings will result. All these, and many other factors have been, and are still being, very closely studied by the progressive malleable founder.

Foreign Investigations

It is impossible to deal properly with the subject of "sand" in this Paper, and for those who are further interested, the author would refer them to the excellent Paper "Present Status of Foundry Sand Investigation and Control," which was presented to the Association Technique de Fonderie in 1935, by William G. Reichert, on behalf of the American Foundrymen's Association. The Paper deals in a thorough manner with the application of sand control, the information derived from various control and special tests, sand classification, the advantages of control; it also considers synthetic sand, coal-dust additions and factors concerning surface characteristics, etc. Synthetic sand represents the most modern development in sand technique, and the subject is receiving the attention of the modern malleable castings founder.

Another Paper which is well worth studying is that presented to the American Foundrymen's Association in 1936 by H. W. Dietert and Frank Veltier.[6] This Paper is of particular interest, since it deals with the properties of sands used in thirteen American malleable cast-iron foundries. The following observations from the summary of this Paper will, no doubt, be of

interest and give an idea of the trend in American practice:—

(1) Though synthetic sands are used quite extensively in malleable iron foundries, natural moulding sands are still used in the majority of plants.

(2) The use of mould dusting powder and mould wash was reported for only two out of 26 samples.

(3) Of the thirteen foundries, eleven reported the use of optical pyrometers for control of metal temperatures. This is of special interest and instances a further step on the part of the malleable founder in the direction of development of progressive practice.

(4) Iron temperatures reported ranged from 1,456 to 1,693 deg. C.

(5) An approximate relationship may be established between permeability and finish. In support of this figures are given of permeability figures corresponding to the terms "smooth," "medium" and "rough" finish, but these are not quoted, because they do not apply universally.

(6) When sand is worked at high strength, a low moisture is desirable and *vice versa*.

(7) An increase of fines, *i.e.*, on Tyler (U.S.A.) standard sieves, 200, 270 and Pan material has a tendency to increase the quantity of moisture required, which is as one would expect.

Reference might also be made to a Paper by the author[7] dealing with the application of science to control of foundry sands, and relating especially to mechanical plants.

Metallic Raw Materials

For the present purpose, annealed malleable scrap, and steel and wrought iron scrap may be regarded as raw materials, and consideration of these is placed prior to pig-iron, because it is suggested that the sequence of developments will be more clearly illustrated by this method of grouping.

Annealed Scrap

A considerable amount of progress has recently been made in the knowledge of the use of scrap materials. For example, it is a fairly generally accepted view that to make first-quality castings by either the white or blackheart process, the amount of annealed scrap in the mixtures should be limited. In England there are still some whiteheart manufacturers who will not permit any annealed scrap in their mixtures, and, at one time, this rule was almost universal; there are others who limit the amount to 5 per cent. The latter figure is recommended as the limit by Pearce and Evans,[8] who state that the continued use of amounts in excess of 5 per cent. of the charge produces short "life" metal.

So far as blackheart metal is concerned, amounts of 5 to 10 per cent. have been quoted from time to time, though it is recognised that many foundries, especially in the U.S.A., use very much greater quantities. In general, the limits mentioned, particularly in respect of whiteheart malleable, are wise ones, owing to the variation in carbon contents of the annealed scrap. However, in the light of modern knowledge, it is not possible to dogmatise on this subject, and the above statements need qualification, as follows:—

The amounts of annealed scrap used in a charge should be controlled not only having regard to composition of metal, but also according to the method of melting. In this connection, a personal experience appertaining to direct cupola melted metal for blackheart malleable may be cited, whereby it was found that the use of more than 3 to 5 per cent. of annealed scrap resulted in reductions in elongation or ductility and yield point values. The cause of this cannot definitely be stated by the author, but he believes that it is related to the question of entire solubility of the temper carbon—which is usually relatively high in amount in cupola metal—before the iron becomes molten, and the possibility of an incomplete mixing in the main body of molten metal which may give rise to an inoculating effect. On the other hand, in processes of melting which permit higher superheating than is obtainable with ordinary cupola melting practices, large percentages of annealed scrap have been used with entire success. In the U.S.A. for example, relatively large amounts of annealed scrap are invariably on the market and some plants incorporate appreciable percentages of this material in their mixture. Schwartz[9] quotes a mixture used in the Kranz triplex process which comprises 55.7 per cent. malleable scrap, 40 per cent. sprue ("as-cast" scrap and runners, etc.) and 4.3 per cent. of pig-iron. This may, however, be considered as an extreme case, and a review of blackheart malleable practices in America, France, Germany and England, indicates that the average amount of annealed scrap in the mixtures varies between 10 and 12 per cent.

Blackheart and whiteheart malleable founders who also make their own annealing pots can incorporate in their pot mixture any excess quantities of annealed scrap which they have, and some plants—perhaps very wisely—consign all their malleable scrap to this mixture.

Steel Scrap

The utilisation of steel scrap in metal mixtures which are used for malleable castings is not by any means a modern innovation. There are records that it was regularly used by one American plant as far back as 1887, and there is little doubt that it was also used many years ago on the Continent and in England. Its use, apparently, soon fell into disrepute generally among makers of both types of malleable cast iron, and it is only within the past 15 to 20 years that steel scrap has found its way back into malleable mixtures, but even to-day it is looked upon with suspicion by many whiteheart founders.

The hesitancy to use this material is accounted for by several reasons, the main of which were lack of metallurgical knowledge and, in many cases, faulty melting practice. At one time it was thought necessary in blackheart practice to avoid metal with lower carbon contents than 3 per cent., whereas modern metallurgical developments have shown that this element should preferably be between 2.3 to 2.5 per cent. and not above 2.7 per cent., while with the types of malleable known as "short anneal" metal, the carbon ranges from 1.9 to 2.3 per cent. Moldenke recommended limiting steel scrap additions to 10 per cent., and Schwartz, in his treatise on "American Malleable Cast Iron" (1922 edition) states that "steel is rarely used in making cupola or electric furnace malleable."

Typical Steel Scrap Mixtures

The extended use of steel scrap in present practice represents an important stage in the development of malleable melting practices, and it is now regularly employed in the production of both types of castings, the quantity used varying very broadly from 5 to 90 per cent. The following examples of steel scrap mixtures are fairly representative:—

(1) The largest European producers of air furnace blackheart malleable use from 5 to 10 per cent. of steel scrap. A French company utilises 5 to 15 per cent.

(2) A large British producer of direct cupola blackheart metal regularly uses 30 per cent., whilst an associated French foundry employs 35 to 40 per cent.

(3) An American plant, operating cupola-electric furnace duplex process, incorporates 40 per cent. steel scrap in their mixtures.

(4) A U.S.A. founder, producing electrically-melted blackheart malleable, records the use of 6 per cent.

(5) Rotary furnace melting practices in France, England, Germany and Italy, for both whiteheart and blackheart malleable cast iron, reveal that steel scrap additions vary from 10 to 45 per cent.

Kluystman,[10] in a very interesting Paper on cupola blackheart malleable, records the use of 45 per cent. It is possible to employ 100 per cent. steel scrap mixtures, plus ferro-alloys, in cupola practice, but as Gailly[11] points out, there is difficulty in obtaining iron of regular analysis from such mixtures when simply cupola melted. Further, in general, these very high percentage steel mixtures are very prone to oxidation and tend to result in "wild" metal which lacks fluidity and shrinks considerably. There is also the economic factor which must be borne in mind, for, after all, beyond certain limits of composition, the only advantage in using steel scrap is the savings in cost compared to pig-iron, and with very high percentages of the former, the savings are very likely to be offset by the excessive amounts of relatively expensive ferro-alloys required. Hurren[12] investigated the effects of the use of steel in whiteheart malleable mixtures, and he expressed the view that up to 25 per cent. steel scrap gave beneficial effects and tended to aid decarburisation. Modern knowledge confirms Hurren's findings (which were made more than 16 years ago), but as previously indicated, with improved melting practices amounts in excess of 25 per cent. are now being regularly and successfully employed.

Careful Control Needed

For successful steel scrap mixture practice melting operations must be carefully controlled to produce superheated metal without excessive oxidation. These conditions are far more easily obtained by the rotary or electric furnace than from the cupola. In the latter case success is possible, however, by very close control of each step in the melting process, such as correct height and condition of coke bed, careful weighing of the metal and coke charges, and the right amount of air at suitable blast pressure. The tapping of the cupola must also be carefully controlled, and the practice of tapping the metal from the furnace at erratic intervals, and in very small quantities, is condemned. With steel scrap mixture practice it is essential to ensure thorough mixing of the molten metal by allowing, at least, one complete charge to collect in the well and/or to collect this amount in a large receiving ladle or receiver forehearth. Tapping at regularly timed intervals is a very advisable procedure as it aids very considerably thorough mixing of the metal, and also uniformity of composition.

Reverting to the amount of steel scrap one can incorporate in a mixture, one's particular requirements, type of casting made and foundry technique, including melting practice, are the governing factors. It is the author's experience that for ordinary cupola melting practice 30 per cent. to 35 per cent. of steel represents a practice that will give the most satisfactory economic advantages without having to contend with the disadvantages of high shrinkage and badly oxidised metal which are invariably associated with higher percentage steel scrap mixtures.

Steel scrap in general, can vary considerably in its characteristics and composition, and it is of particular importance in the manufacture of malleable castings that such material be carefully selected. For example, in these days of alloy steels, a somewhat new danger arises unless precautions are taken; manganese and chromium steels have found their way into malleable foundry scrap yards and sometimes into the mixtures, with disastrous results.

Effect of Chromium in Scrap

Analytical examination must include accurate determination of the chromium content; this is the most dangerous element to have present in blackheart malleable which is required to possess maximum ductility, as it is a powerful inhibitor

of graphitisation. Touceda[13] found that less than 0.1 per cent. chromium will result in the castings being hard or brittle after annealing, and that even 0.06 per cent. chromium creates deficiencies in ductility, causes abnormal fractures and reduces machinability; he places the safe limit at less than 0.035 per cent. chromium. Peace[14] has also recorded that even 0.01 per cent. chromium retards the annealing of blackheart malleable to some extent. It is, however, doubtful if any malleable castings are made with as little as 0.01 per cent. chromium owing to the difficulty of securing raw materials free from chromium. The author places the amount of chromium which is usually found in ordinary blackheart malleable castings at between 0.02 and 0.04 per cent.

The effect of chromium on whiteheart metal is not so marked, as the influence of this element on decarburisation is not so great as it is on graphitisation. There is, however, need to control the amount, and the permissible limit for this type of metal is in the neighbourhood of 0.1 per cent. Acceptance of nickel in steel scrap should be limited to 0.05 per cent. and hence, shafting or similar scrap should be avoided as such steel often contains appreciable quantities of nickel.

The malleable founder must not ignore the fact that nickel is a powerful graphitiser—1.0 per cent. being roughly equivalent to 0.3 per cent. silicon—therefore, if the possible presence of this metal is ignored, trouble may arise due to fine primary graphite. The presence of microscopically fine particles of primary graphite have a very detrimental effect upon the mechanical properties of either types of malleable, and may account for some of the apparently mysterious failures; it is a subject well worth further serious investigation. Very rusty steel is also detrimental, and scrap which is so rusty that it "scales" should not be used. Small steel, such as punchings, should also be avoided, while constructional steel (rails and fishplates), "crop" ends, and similar materials are suitable subject to the stipulations given above.

Finally, with regard to steel scrap, it should always be examined for wrought iron, which often becomes incorporated with it; obviously, mixed wrought iron and steel scrap will create variability in chemical composition, particularly in respect of the manganese contents. As to the use of wrought iron alone, there appears to be a few continental foundries who use it. It should, in general, be viewed with suspicion as the cheaper grades of wrought iron contain appreciable quantities (0.3 per cent. or more) of phosphorus.

Pig-Iron

It has previously been pointed out that early malleable cast iron was made from white or mottled hematite pig-iron for which there had previously been no demand. Suitability of the iron was judged by fracture grading, and such practice is still very largely in use among some of the small whiteheart foundries. Typical English malleable pig grading is represented by the following: White, spotted white, hard mottled, medium mottled, soft mottled, grey. This method of grading did not take into account chemical composition and, undoubtedly, lack of uniformity in quality and mechanical properties of much whiteheart malleable was largely due to the very wide variations in chemical composition of these pig-irons. For example, it was, and still is, possible for some "white" grades to contain as much silicon as some of the "grey" grades. Blast-furnace conditions alone can also account for these wide variations in fracture appearance, though invariably the high sulphur contents have an important influence in this direction.

The sulphur is rarely less than 0.2 per cent. and often amounts in excess of 0.3 per cent. have occurred. It is well known that sulphur retards annealing and decarburisation, and if excessively high, gives rise to "peeling" or scaling of the castings after annealing. This element also effects the fracture of the pig-iron by promoting a chilling effect which is also carried through to the castings and this is likely to give a deceptive appearance to the fracture of them, especially if the amount varies, so that for a given silicon and annealing cycle, an unsatisfactory product may easily result in practices where the suitability of iron is judged by the "rule of thumb" method of examining fractures.

It would probably be true to state that the first development of real importance in the malleable industry was the application of chemical analysis to the examination and subsequent control of the pig-iron and resulting metal for the castings. The information gained, coupled with knowledge gleaned from early researches on the effects of the various constituents in cast iron, undoubtedly led to some malleable founders demanding pig-iron which would be more uniform in composition than the old types of white to grey or soft mottled hematite irons.

Refined Pig-irons

The foundrymen's demand was met, to some extent, by the introduction of the so-called "refined" pig-irons, which marks another stage in the history of whiteheart malleable. These irons were lower in carbon and manganese than hematite iron, but there was little, if any, refinement so far as the sulphur content was concerned, and, in many cases, the variations in silicon content were very considerable. Further, they were usually made by merely remelting hematite pig-iron in cupolas and usually under very oxidising conditions, so resulting in lower carbon, which was often further reduced by adding steel with the hematite iron. The resulting metal was usually cast into chill moulds, and, at this stage, the practice of mixing by fracture broke down.

Many founders did not realise that such pig-iron was white through the effects of chilling and not because of composition. A striking example of this has been quoted by Field,[15] who refers to a consignment of iron, all the pigs of which exhibited the same fracture, yet the silicon contents varied from 0.6 to 1.65 per cent.

Foundries which used the old fracture method of control had many costly experiences with irons of this type, just as much as with the straight hematite irons, due to lack of knowledge of this chilling effect and variation in the composition. Obviously, the irons with widely varying silicon contents, referred to above, would, when remelted, permit the silicon to revert to its control of the carbon conditions and, with the high silicon pig, primary graphite formation would take place in many of the castings. On the other hand, the high silicon iron would have been grey had it been cast in sand, and hence would not have been accepted by many founders on the grounds that it was not possible to make malleable castings satisfactorily from pig-iron of a soft grey fracture. This view is still held by quite a number of whiteheart makers, yet there are many foundries, particularly on the Continent, producing this type of malleable from mixtures which involve the use of fairly high silicon (1.5 to 3.0 per cent.), low sulphur, grey fracture, ordinary hematite pig-iron. Such practice has long been associated with the blackheart malleable industry. In the former industry, however, the use of this class of iron, coupled with a balanced sulphur-manganese ratio and controlled cupola practice to give as low a sulphur pick-up as possible, is a modern development. The resulting advantages are lower costs, especially if steel scrap is also incorporated in the mixture, and a more reliable, uniform and ductile product. The essentials for the successful manufacture of whiteheart malleable castings from grey hematite pig-iron, steel scrap and scrap mixtures are:—(1) Analytical control of raw materials; (2) careful selection and proportioning of the constituents that go to make up the metal charges; and (3) thorough control of cupola or other melting practice at every step to ensure that metal of uniform composition, free from excessive oxidation and of high temperature, coupled with maximum fluidity or "life" shall be obtained.

Modern Refined Irons

A most important English development has been the introduction, during the past fifteen years or so, of the modern high-quality irons which can correctly be termed "refined" pig-irons. There are numerous processes for making these, but, as a general rule, the open hearth and the rotary furnace methods produce the lowest carbon and sulphur iron. These modern pig-irons are very much more uniform in composition and fracture than the old type "refined" materials.

The ideal way of producing iron from the crucible or cupola for black or whiteheart castings is to use metal charges consisting of modern refined pig-iron and unannealed (foundry) scrap. It must, however, be borne in mind that it is easy to ruin excellent iron by bad melting practice. Refined iron is not made, nor ever will be, to produce good castings regardless of how it is melted.

Where competition or the economies of production prevent one from using genuine refined pig-iron on account of its relatively high cost, development of the high silicon hematite pig, steel scrap, and scrap mixtures has materially helped in meeting the situation.

(To be continued.)

Effect of Span on the Transverse Test Results for Grey Cast Iron

As a result of some research work, the details of which were presented to the 40th annual meeting of the American Society for Testing Materials, Dr. J. T. MacKenzie and Mr. C. K. Donoho have drawn the following conclusions:—(1) Modulus of rupture increases with decreasing span; (2) deflection, of course, decreases with decreasing span, but the decrease is much less than the conventional beam formula would indicate; (3) modulus of elasticity decreases with decreasing span; (4) the rate of change of the values from de Lavaud strips with decreasing span is generally greater than that of the values from mono-cast strips. This is evidenced by the C^* values, which show the C for the de Lavaud test to be roughly twice as large (numerically) in each case; and (5) the amount of the effect of changing span depends largely upon the qualities of the iron.

Estimation of Cadmium

Volatilisation of cadmium from alloys rich in tin can be made so complete without appreciable loss of tin that it has been adopted as a method of analysis. In a recent publication, Professor D. Hanson and Dr. W. T. Pell-Walpole have described the procedure they have developed during their investigations on the constitution of alloys of cadmium and antimony with tin. The alloy is weighed into porcelain combustion boats which are then maintained at 700 to 730 deg. C. for thirty minutes in a silica tube connected to a vacuum pump to assist the volatilisation of the cadmium. Several estimates may be made simultaneously. The degree of accuracy was checked and found to be perfectly satisfactory. The method is described in Technical Publication Series A, Number 55 of the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C.2, from whom copies may be obtained on application.

* C = constant which determines the rate at which the test result departs from the ultimate value with decreasing spans.

The Corrosion of Low-Copper Content Cast Iron by Dilute Sulphuric Acid*

By JOHN R. MARÉCHAL

It has long been known that copper has a beneficial action on the resistance of iron to attack by hydrochloric acid. This research carries the subject to the behaviour of low-copper content cast iron on attack by sulphuric acid of various concentrations. In order to ascertain exactly this behaviour it is necessary to measure the loss of weight as a function of time for each concentration. The researches are confined to the measuring of loss of weight every twenty-four hours at ordinary temperatures. The first step was to verify if, for the irons examined, the loss of weight remained constant at the end of a fixed time. For this purpose the author very carefully removed the corrosion products which adhered to the test-piece and continued the attack during the same period of time in fresh acid. The parallelepipedic test-piece was placed on three pieces of glass formed like a cross in a Berlin beaker, and it was held thus in three positions by means of two lower supports. Thus the corrosive liquid could wash the whole of its faces. On each occasion the sample was placed at the same depth and at the same distance from the walls, in order always to operate under the same conditions. The concentration of the acid was calculated as a volume starting off with the commercial figure of 60 deg. B.

Six experiments were made under these conditions and the results obtained were reasonably concordant; thus for an iron subjected to an attack by a 15 per cent. acid the loss in weight given in milligrams per square millimetre (for the purpose of these calculations the author used the average of the surface areas before attack and after cleaning) was 1.29, 1.31, 1.29, 1.32, 1.28, 1.30, which gave an average of 1.3 mg. per sq. mm. per 24 hrs.

The irons used for this research, and referred to as C, were cast from a pulverised fuel rotary furnace, and had the following average composition:—T.C, 3.4; Si, 2; Mn, 0.47; S, 0.1; P, 0.1 per cent.; and Cu, variable.

The resistance to transverse stresses on small test-bars (Thyssen-Bourdouxhe Machine) averaged from 38 to 42 kg. per sq. mm. and the tensile strength from 18 to 20 kg. per sq. mm. According to the system detailed above the average of six figures corresponding to six attacks of twenty-four hours each, the following results have been obtained:—

Irons.	H_2SO_4 concentrations.				
	1 per cent.	2 per cent.	5 per cent.	10 per cent.	15 per cent.
C 1	1.408	1.80	1.73	1.50	1.31
C 2	0.605	0.77	1.052	0.10	0.77
C 3	1.419	1.81	1.68	1.53	1.30
C 4	1.441	1.88	—	—	1.35
C 5	0.769	2.293	1.603	1.44	1.29
C 6	0.76	1.196	1.54	1.35	1.20

If these figures are set-out in diagrammatic form with the acid concentration as abscissæ and average loss in weight in mg. per sq. mm. as ordinates the curves shown in Fig. 1 are obtained. These curves have a characteristic shape resembling a dome, quickly rising for low acid concentration, reaching a maximum for a concentration which varies with each copper content and decreasing relatively slowly. One can set-out a characteristic for an iron by a coefficient which will indicate the maximum loss of weight in mg. per sq. mm., and by the side of which one can attach the figure for the corresponding acid concentration according to the following formula

$$\frac{P}{C} = \frac{2.44}{0.65}$$

which will indicate the maximum corrodibility for an ordinary cast iron (top curve, Fig. 1) which lost 2.42 mg. per sq. mm. in twenty-four hours in 0.5 per cent. dilute H_2SO_4.

The determination of the coefficient can be rapidly made by taking only three carefully chosen points. From experience of these tests, the three points will be easily ascertained. If the points fail to align themselves, a fourth point is taken, this should fall below the maximum and the line is continued as far as is necessary, and from then onwards it is possible to draw a curve more or less exactly according

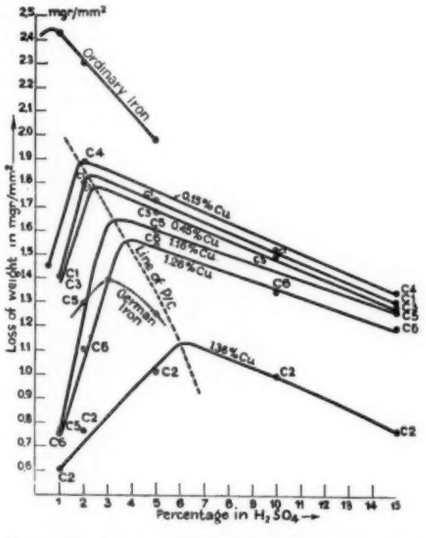


Fig. 1.—Characteristic Curves for the Corrosion of Low-Copper Content Cast Iron by Sulphuric Acid.

to the number of points obtained, to include the region of the maximum. This has been done with iron O (ordinary iron, Fig. 1). The points 2.424 mg. per sq. mm. corresponding to 1 per cent. H_2SO_4; 2.3 mg. per sq. mm., corresponding to 2 per cent. H_2SO_4 and 1.98 mg. per sq. mm. were first ascertained. Then it was possible to place the maximum between 0 and 1 per cent. H_2SO_4, after which a dome-shaped curve was drawn by extending the right side to correspond with the three ascertained points and so it was thus possible to postulate a coefficient of maximum corrodibility, in this case in the region of 2.44 mg. per sq. mm. It should be noted that this curve relating to iron O clearly separates itself from the group of curves determined for copper-bearing irons and it does not follow the same form. This is understandable, as iron O is copper free and hence it has been cast under different conditions, and consequently its structure is somewhat different from irons C, and it only serves as a point of comparison. Moreover, the characteristic curve has been determined for a copper-bearing iron of German origin carrying 0.08 per cent. Cu, and it too separates itself from the group C for the same reason. It has not been cast under the same conditions and the composition is not quite of the same order. Whatever the iron may be, however, the dome-like form of the curve persists, and there are the three average figures:—

H_2SO_4 concentration point.	Loss in weight in mg. per sq. mm.
2	1.3
3	1.39
5	1.1

which give the maximum corrodibility coefficient as

$$\frac{P}{C} = \frac{1.39}{3.00}$$

The characteristic curve of this iron is shown as dotted lines in Fig. 1 and the following Table shows the maximum corrodibility figures for iron C—specially studied:—

Irons.	$\frac{P}{C}$.
C 1	1.83/2.30
C 2	1.14/6.00
C 3	1.78/2.45
C 4	1.89/1.85
C 5	1.65/3.30
C 6	1.56/3.80

To control the copper content of the various irons recourse was had to a colorimetric test based on the property which very dilute solutions of copper salts have of being more or less blue according to the number of copper ions they contain,* and this has been used as standard since 1930. The following Table gives the results of the analysis of copper given by ordinary and the colorimetric methods:—

Irons.	Chemical analysis.	Colorimetric estimation.
C 1	0.16	0.15
C 2	1.36	>1.20
C 3	0.48	0.40
C 4	0.19	0.15
C 5	0.17	1.15
C 6	1.28	1.25

No attempt has been made to check the copper content of C 2 because of the previous absence of a scale reaching beyond 1.20 per cent. copper. Since then a second scale has been constructed. If the irons are classed in order of decreasing maximum corrodibility and against them tabulate copper contents, the following Table is given:—

Irons.	$\frac{P}{C}$.	Average Cu content.
C 4	1.89/1.85	0.15
C 1	1.83/2.30	0.15
C 3	1.78/2.45	0.45
C 5	1.65/3.30	1.16
C 6	1.56/3.80	1.26
C 2	1.14/6.00	1.36

This Table shows that the order corresponds to increasing copper contents. Moreover, it is possible to say that the critical concentrations are displaced in the direction of increasing sulphuric acid contents. This is clearly shown in Fig. 1, and the critical points align themselves on a continuous curve.

Spanish Iron Ore

An official communique from Salamanca states that exports of iron ore from Bilbao to Great Britain, Holland and Germany will be resumed shortly except where the Franco Government "is compelled to take special measures in view of political or economic considerations." Large stocks of ore are reported to be ready for export, but there is a shortage of skilled labour.

* Extracted from the Bulletin Scientifique de l'Association des Elèves des Ecoles Speciales.

* "Colorimetric Method for Analysing Copper in Copper-Bearing Irons and Steels," by John R. Maréchal.

Feeding Aluminium-Alloy Castings*

FUNDAMENTAL PRINCIPLES GOVERNING THE ELIMINATION OF CERTAIN DEFECTS

By R. PERRET

Defects Observed

Castings of aluminium alloys (aluminium-copper, aluminium-magnesium alloys, Alpax metal, etc.) frequently exhibit the following defects:—

(1) *Blowholes*, which are generally situated in the portions of the casting forming the "crown," that is to say all the upper portions of castings, the impression of which in the mould is horizontal or slightly inclined when pouring. These blowholes are not apparent on the rough casting. They are separated from the surface by

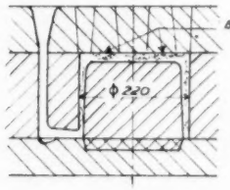


FIG. 1.

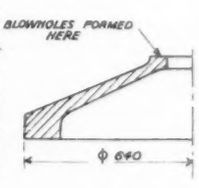


FIG. 2.

a thin skin of metal and are revealed either by sandblasting or at the commencement of machining. If the mould contains metal chills in the crown, there is a tendency for blowholes to be more numerous in the vicinity of these chills. Figs. 1 and 2 show castings in the pouring position, indicating the regions where blowholes are formed.

(2) *Films* of oxidised metal imparting to the surface of the casting a very characteristic "wrinkled" and dirty appearance. This defect is generally localised near the ingates. It is more frequent and more pronounced in castings of metal that is relatively more oxidisable when hot. This defect is found more frequently in aluminium-magnesium or Alpax metal castings than in aluminium-copper castings.

The two defects just referred to are very seri-

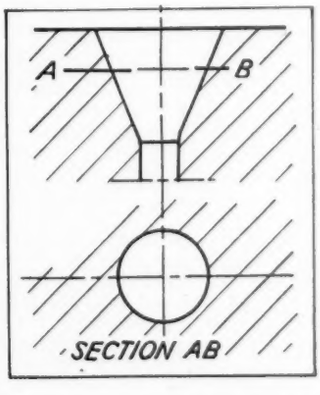


FIG. 3.—CONICAL-SHAPED RUNNER OF CIRCULAR CROSS-SECTION.

ous, because they often result in the rejection of castings, or at least in very expensive and never very reliable repairs by welding or other methods. According to the shape or purpose of the casting under consideration, these two defects may give rise to special defects, such as exudation during the hydraulic pressure test for castings which have to be water-tight, and abnormally low mechanical properties of the metal as cast (particularly the resilience).

Origin of the Defects

Blowholes.—Although sometimes the cause of some of the above-mentioned defects may be "accidental," such as the use of sand which is too wet or is rammed too tightly, badly stoved cores, etc., almost all are due quite simply to incorrect feeding of the moulds. Actually, the moulder has usually a tendency to make the downgates of large cross-section on the pretext, so he says, of ensuring a casting of good appearance. Then, again, he gives the runner a conical shape of circular cross-section, this being easily cut in the sand by rotating the tool (Fig. 3).

It follows from these two considerations that, at the moment of pouring, and principally at the commencement of the introduction of the metal, it is materially impossible for the workmen to pour enough metal to fill the downgate and to keep it full, because of (*a*) the excessive rate of flow which this would necessitate in view of the considerable cross-section of the downgate, and (*b*) the circular cross-section of the pouring hole, which, when pouring from rather large crucibles (600-lb. (brass) crucibles for example), are thus difficult to manipulate. This makes it necessary to have a relatively low rate of flow of metal, because the width of the stream of metal increases very rapidly with the inclination of the crucible, and there is a risk of metal falling outside the runner if an attempt is made to increase the flow (Fig. 4).

Air is thus carried along with the metal, since the gate cannot be kept full for the two reasons stated above. Very often, the amount of air carried along in this way is increased by the gyratory motion of the metal in the conical pouring hole, this motion creating an air current. Some of the air introduced into the mould in this way with the metal may be absorbed by the latter, but the greater part of this air forms bubbles in the body of the metal, which are enveloped by an oxide film as a result of the ease of oxidation of the molten metal. These bubbles move through the mould and, due to their low density, naturally lodge in the upper portions of the mould (it should be noted that the bubbles retain their spherical shape on account of the high surface tension of the oxide film enveloping them). If the casting be thin, however, the metal cools rapidly and the bubbles being thus arrested in their path are to some extent distributed throughout the casting and even on the vertical walls.

If the mould is provided with crown chills, they favour the formation of blowholes in that region. The difficulty is therefore experienced of having to remove air from the mould since it cannot escape through the chill and remains so to speak imprisoned between the metal rising in the mould and the chill.

Films of Oxidised Metal.—When left to his own initiative, the moulder arranges the downgate and ingates at those places which are most convenient from the point of view of his own work or which facilitate subsequent cutting and dressing. Very often one finds vertical downgates of considerable depth, leading the metal at right-angles to the ingates, and very often also these ingates direct the stream of metal at right-angles on to a core or cause the metal to descend in the mould from a considerable height (Fig. 5).

Mould Impact Effect

Consider a mass m of metal from the time it leaves the crucible at D (Fig. 5) to the moment at which it arrives at the place it is to occupy in the mould. This mass m of metal is subjected on its path to the action of various forces, in particular gravity and the pressure exerted on each of the boundary sections xx' and yy' of the mass m. The resultant of these various forces (which moreover may be of different values during the descent of the metal; for example, gravity does not act between A and B) imparts to the mass m a definite movement of velocity V at a given instant. The kinetic energy of the mass m is then $E=\frac{1}{2}mV^2$.

The friction of the molten metal against the sand or metal of the mould and the internal friction of the metal itself due to its viscosity

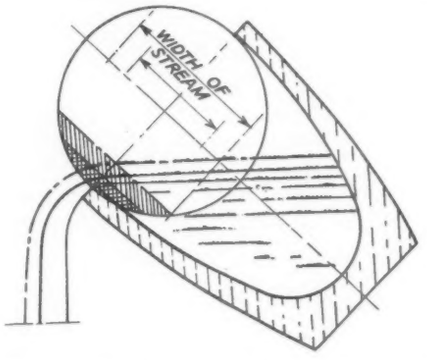


FIG. 4.—VARIATION IN THE WIDTH OF THE STREAM OF METAL WITH THE INCLINATION OF THE CRUCIBLE.

will absorb this energy if it is not excessive, that is to say as long as the velocity V does not exceed a limit value V_1 which may be called the limit velocity of flow of the metal under consideration. If the velocity V of the metal is greater than this limit velocity V_1, the available energy of the metal will not be expended entirely in friction, and when the metal enters

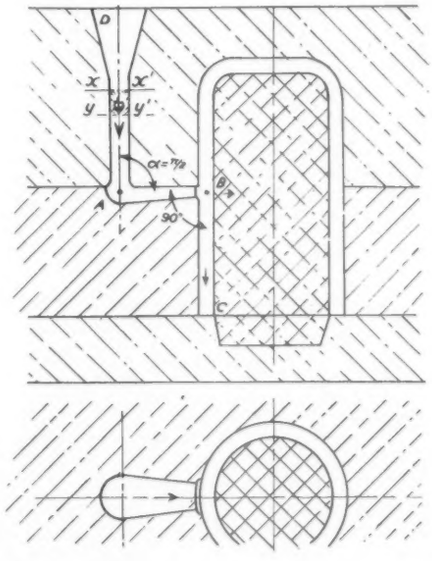


FIG. 5.—VERTICAL DOWN-GATE WITH INGATE AT RIGHT ANGLES.

the mould cavity at B, its available energy will again produce turbulent motion and spurting of the metal. The oxide film covering the metal will thus be ruptured and consequently there will be an increase in the oxidation surfaces accompanied by the formation of fresh oxide films until the metal reaches a certain

* Paper presented to the International Foundry Congress held in Paris.

height in the mould, when the pressure exerted on yy' will reduce its velocity to a value below V_1.

The oxide films thus formed have a density approximating to that of the metal. They form films of "scum" which generally remain localised in the vicinity of the ingates and impart to the casting a characteristic wrinkled and greyish appearance. It may happen, however, depending on the shape of the casting, that these scum films are dispersed in somewhat haphazard fashion throughout the entire casting and cause exudation during the hydraulic pressure test or form weak sections which act as the origins of fracture when the casting is subjected to mechanical tests, particularly impact tests.

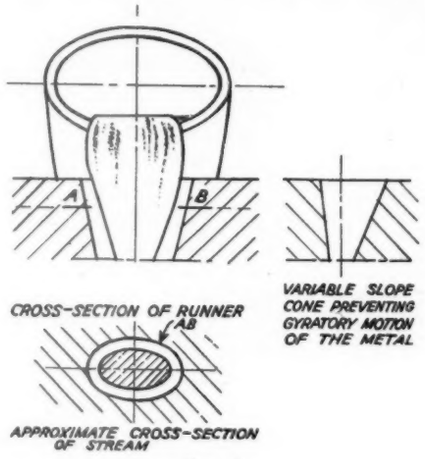


Fig. 6.

Remedies Considered

The defects just discussed would be eliminated if it were possible to prevent the oxidation of the metal and the carrying of air along with the metal. A radical solution would obviously be to pour the moulds in a special evacuated chamber. Unfortunately, in the present position of technique, this solution is difficult to realise in practice on an industrial scale. One is therefore obliged to search for improvements in pouring moulds under ordinary atmospheric conditions, as practised at the present time.

Elimination of Blowholes in the Crown.—This is a relatively simple matter since, as already indicated, it is merely necessary to prevent air from being carried along mechanically by the metal. For this purpose, the runner should be kept constantly full of metal and this result will be attained if:—

(*a*) The cross-section of the downgate (but not the cross-section of the ingates) is not too large so that the flow of metal will be moderate and the crucible will not have to be tilted excessively in order to obtain this flow. When pouring with crucibles of 600 lbs. (brass) capacity, experience shows that the rate of flow of 1.6 to 1.8 lbs. per sec. is a maximum not to be exceeded. It should be noted that it is quite possible to produce perfect castings with rather small downgate cross-sections (14 mm. dia., for example, for castings requiring with their feeding heads a weight of 6.3 lbs. of metal), without having to pour very hot.

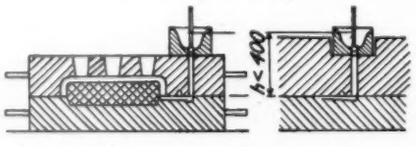


Fig. 9.—Two Positions for Pouring Basin.

(*b*) The workmen in charge of pouring should also be able to pour freely into the hole, ensuring the normal rate of flow from the commencement of pouring. For this purpose, it is merely necessary to make the runner of oval cross-section, the major axis of the oval being parallel to the largest dimension of the stream (Fig. 6). Furthermore, if care be taken to give a variable slope to the runner, as indicated in the cross-sectional view, it is possible to prevent the gyratory motion of the metal in the hole and to obviate the risk of air being carried along by the metal in this motion.

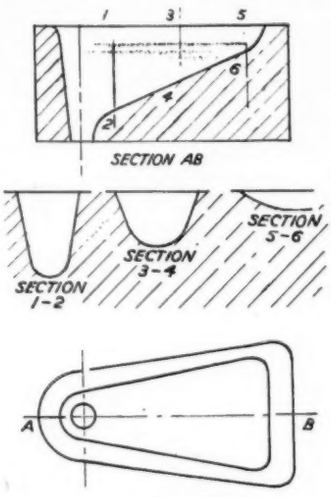


Fig. 7.—Plain Pouring Basin.

If the mould is of some considerable size, and consequently requires a relatively long time to fill, or if the casting be thin and of considerable surface and requires a high rate of flow, there is a danger that the workmen will fail to keep the gate full of metal. In this case, a certain volume of metal which will act as a reservoir and regulate the rate of flow must be provided between the crucible and downgate.

This will thus entail the use of a pouring basin, either plain or with a stopper (Figs. 7 and 8). The basin with stopper is preferably employed for pouring large castings or those requiring a high rate of flow, because it provides a considerable reservoir of metal without the dimensions being excessive. These two types of basin may be made of oil sand, such as is used for cores, or of refractory materials, and may be used for pouring several moulds if care is taken to remove them as soon as pouring is finished and before the metal has solidified in the interior. The stoppers are very easily made from graphite electrode ends by turning them to shape on a lathe.

The pouring basins are placed either directly on the upper part of the mould or are let into that part (in the latter case, the basin can obviously only be used once), the selection depending upon the height of fall of the metal, as will be seen later (Fig. 9).

In addition to the foregoing considerations, which should be scrupulously observed to prevent any air from being carried along with the metal, it is expedient, when making the pattern, to allow a greater thickness for machining on the portions situated in the crown than on other machined parts. This extra thickness makes it possible to eliminate the small blowholes which may be produced during the passage of the metal in the interior of the mould, due to the particular shape of the latter. Finally, it is necessary to avoid as far as possible placing chills in the crown, and if they be unavoidable, grooved chills which allow the gases imprisoned in the mould to escape should always be used (Fig. 10).

Elimination of Oxide Films.—As has been shown the problem in this case is to limit the kinetic energy of the metal entering the mould, or what comes to the same thing, to keep the velocity of the metal below a limit value which has been termed the limit velocity of flow and above which the oxide film surrounding the metal is ruptured.

Determination of the Limit Velocity of Flow of a Metal

The velocity may be determined with a sufficient degree of approximation for practical purposes by allowing the metal under examination to fall into a vessel (crucible) containing metal, with increasing heights of fall, and making arrangements so that the rate of flow is constant. A note is made of the height of fall corresponding to the appearance on the surface of the bath of oxide films forming in contact with the air in consequence of the rupturing of the original skin enveloping the metal.

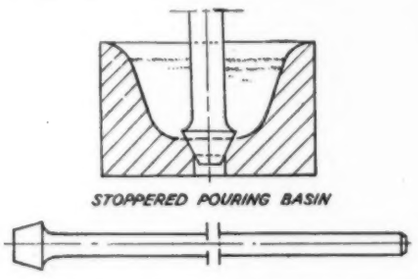


Fig. 8.—Stoppered Pouring Basin and Stopper.

For Alpax metal, this height of fall is in the vicinity of 0.32 metre. It corresponds to a velocity V of the metal $= \sqrt{2gh} = \sqrt{2 \times 9.8 \times 0.32}$ = about 2.50 metres per second.

Applications to the Moulding of Alpax Metal Castings

Knowing the limit velocity of flow of Alpax metal, it is possible to make some observations concerning the moulding of castings of this metal. The same observations may easily be made concerning any other metal, once the limit velocity has been determined.

(*a*) *Height of maximum fall which should not be exceeded.* This height of fall is found in the above-mentioned test. In this test all the energy of the metal is expended in friction due to the viscosity. In the case of a sand or metal mould, however, allowance must be made for the expenditure of a certain portion of this energy in friction against the sand or metal of the mould. Experience shows that for ordinary downgates of circular cross-section and normal dimensions, it is possible to admit a height of fall a little greater than that indicated above, namely, up to about 0.40 metre.

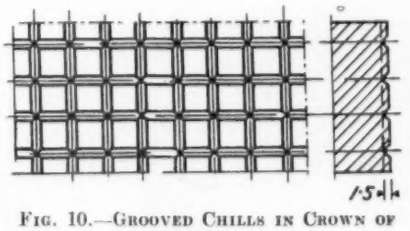


Fig. 10.—Grooved Chills in Crown of the Mould.

This likewise shows that it is essential to place the ingates as low as possible on the casting, so as to reduce to a minimum the fall of metal in the mould. Fountain gating should therefore be employed whenever possible. If for some reason or other it is impossible to make a downgate or ingate with a height of fall of less than 400 mm., it will be necessary to increase the

angle α of the change in direction of the metal. The curve in Fig. 11 shows that the limit velocity increases with this angle (application to circular castings, where it is always advantageous to arrange the ingates tangentially).

(*b*) *Wide Ingates.*—In order to reduce the velocity of the metal entering the mould, it is advantageous to make use of this type of gating,

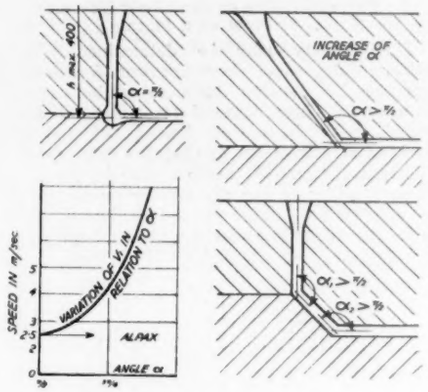


Fig. 11.

that is to say, to make the ingates of a definitely larger cross-section than the downgate cross-sections.

The ratio of the cross-sections may vary from 2 to 5 according to the castings. For example, for a cylindrical downgate 20 mm. dia. and consequently having a cross-section of 314 sq. mm., the ingate cross-section may be 800 to 1,000 sq. mm. To ensure a good distribution of metal and heat in the casting and also to facilitate

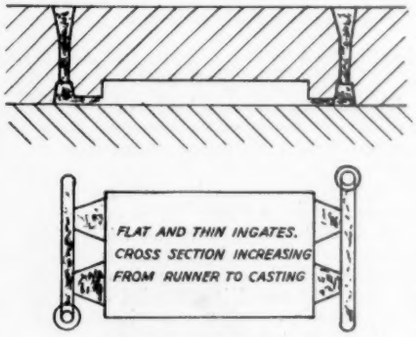


Fig. 12.

dressing, it will be quite natural to make the cross-section of the ingates of a very long and thin rectangular shape (wedge gating) (Fig. 12).

Conclusions

The feeding of moulds plays an essential part in foundry practice in general and in the casting of light metals in particular on account of the considerable ease of oxidation of the latter. It has been shown that by taking some simple precautions it is possible very easily to produce absolutely correct castings of very high quality, which is obviously the object of all conscientious foundrymen.

Cetal

According to "Giessereipraxis," a new aluminium-silicon alloy, "Cetal," with similar properties to "Silumin" has been developed by G. Welter and J. Czochralski. It has the composition of Si 6.5, Zn 10, and Cu 3 per cent. with the remainder aluminium. The properties are not influenced to any marked extent by small fluctuations in the composition, and an addition of 0.3 per cent. Mg has a beneficial effect. Impurities of tin, lead, iron and titanium should not, however, exceed a total of 1.0 to 1.2 per cent.

Costing in a Grey-Iron Foundry

By E. E. Beckett

The author of this article supports certain views expressed during the Derby Conference of the Institute of British Foundrymen, that the Report submitted by the Costing Sub-Committee is too complicated for the ordinary jobbing foundry, and submits what he deems to be a simplified scheme.

Fundamental

All outgoings must be allocated under one of the following headings:—(1) Direct labour; (2) indirect labour; (3) direct materials; (4) indirect materials; and (5) overhead charges.

Procedure

The determination of the labour cost is the simplest side of costing, as the figures are very easily obtainable.

(1) *Direct Labour.*—This merely represents the time booked by the moulder to the job number authorising the manufacture of castings. *Each week the moulders' wages must be totalled separately.*

(2) *Indirect Labour.*—The indirect labour includes wages paid to labourers, coremakers, trimmers and all remaining employees (excluding staff), with the notable exception of the furnaceman. *Each week the total wages paid to these operatives must be ascertained.*

(3) *Direct Materials.*—Each month a careful statement must be prepared giving quantities and values of all materials used which can be allocated to the cost of the metal poured from the cupola. The chief items will be as follow:—(*a*) Pig-iron; (*b*) scrap iron; (*c*) foundry coke; (*d*) limestone; (*e*) ganister; (*f*) fluxes; and (*g*) furnaceman's wages.

(4) *Indirect Materials.*—Under this heading should be allocated all materials used in the foundry that do not actually go to the making of castings. The most important are as follow:—(*a*) Floor sand; (*b*) coal-dust; (*c*) plumbago; (*d*) core creams and gum; (*e*) furnace coke; (*f*) core sand; (*g*) sprigs, chaplets, etc.; and (*h*) power for plant. Here, again, a complete statement must be prepared monthly giving quantities and values of materials expended, the power expenditure being determined by taking one-twelfth of the annual power bill.

(5) *Overhead Charges.*—Under this heading all other expenditure must be allocated and totalled annually in order that a monthly figure may be obtained. Principal items under this heading should be the following:—(*a*) Office salaries; (*b*) carriage inwards and outwards; (*c*) telephone and stationery; (*d*) rates and taxes; and (*e*) insurances.

An easy way of obtaining this figure is to deduct the annual expenditure upon items 1, 2, 3 and 4 from the expenditure side of the last balance sheet and take one-twelfth as the monthly figure. However, when a new costing system is commenced some knowledge as to the overhead figure is generally available, and should be used until the system outlined here has been in operation for twelve months when the *actual* figure may be obtained.

Application

After the foregoing rules have been followed for a few months, the following data should be available:—

(*a*) Ratio of direct labour to indirect labour.
(*b*) Ratio of direct materials to indirect materials.
(*c*) Cost of metal (*per cwt. of good castings sold*) at cupola spout.

A Practical Example

Assuming that a moulder took 10 hrs. to mould a 2-cwt. casting, the cost may then be determined from the above data as follows:—

	£ s. d.
Direct labour (10 hrs. at 1s. 6d. per hr.)	0 15 0
Indirect labour (assuming indirect wages bill to equal direct wages bill)	0 15 0
Direct materials (assuming metal at cupola spout to be 10s. per cwt.)	1 0 0
Indirect materials (assuming indirect exp. to be 20 per cent. of direct)...	0 4 0
	£2 14 0
Works Cost of Casting.	
Overheads (assuming that monthly overhead expenditure equals half-cost of all other monthly payments)	1 7 0
Actual cost of casting without profit...	£4 1 0

General

To round off the results obtained from the simple principles laid down in the foregoing, at the end of each month the following information can be obtained which will give the small foundry owner all the information he requires on the month's working:—

	£ s. d.	£ s. d.
Total value of castings sold as per invoices ... ... (say)		1,000 0 0
Total direct wages bill for month ... (say)	200 0 0	
Total indirect wages bill for month ... (say)	200 0 0	
Total direct materials expended during month (say)	150 0 0	
Total indirect materials expended during month ... (say)	30 0 0	
Monthly index overhead figure ... (say)	200 0 0	
		780 0 0
Actual gross profit for month ...		£220 0 0

Conclusion

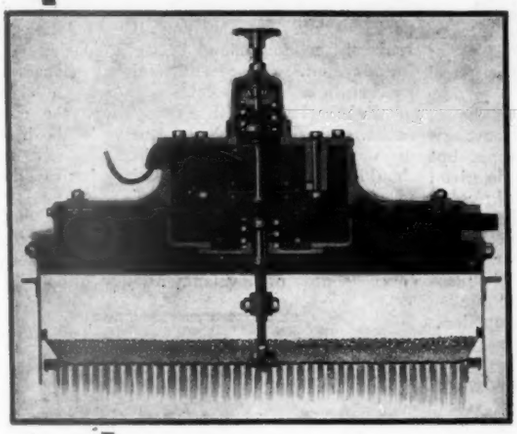
It must be understood that although all the questions that arise from time to time in a foundry as to the proper allocation of labour and materials may not be answered in this article, as long as all items of expenditure are included under one or the other of the five headings set out in the introduction, the desired monthly result *must* be obtained.

The following useful forms and books are necessary to the scheme:—(*a*) Wages book; (*b*) direct materials stock book; (*c*) indirect materials stock book; (*d*) book for posting all overhead expenses; (*e*) time sheets for moulders, and (*f*) record cards for recording moulders' time on castings filed under pattern numbers, and giving weight and selling price per cwt. of castings.

Should any reader require additional information or enlightenment on any point which does not appear to have been made sufficiently clear, the author will be pleased to answer queries through the medium of the Journal.

Holiday Pay Discussions

Representatives of the Welsh Engineers' and Founders' Association and of their employees met at Swansea recently to consider again the question of holidays with pay. At the close it was intimated that the employers had been unable to accede this year to the men's application and that it was impracticable to grant a bonus. The principle was approved and the matter will be further discussed.



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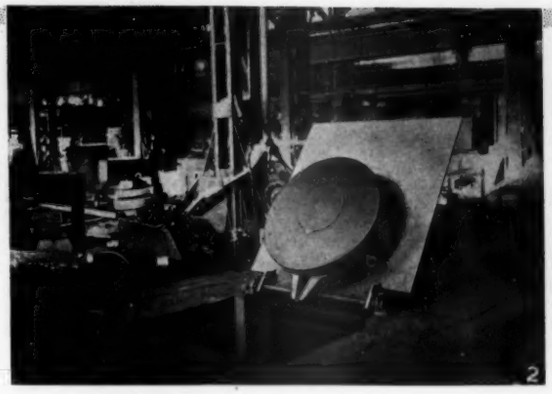

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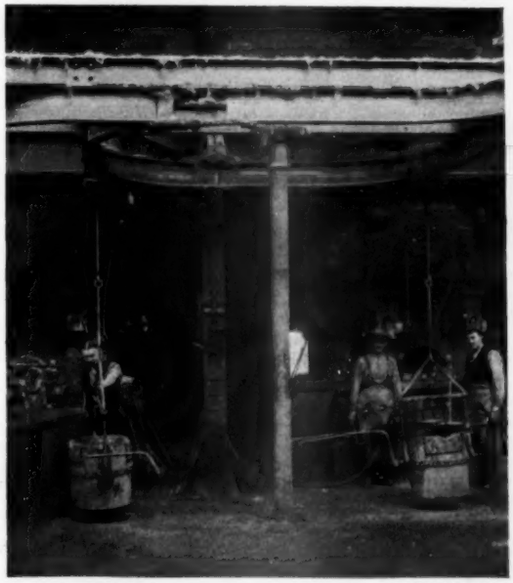

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New Outlets for Steel Castings*

By R. LEMOINE

The sphere of application of steel castings has been enlarged during recent years, though some losses have to be recorded. The final outcome, however, seems favourable, both from the quantity as well as the value points of view. The progress has often been registered at the expense of other foundry products, both iron and non-ferrous, but sometimes steel castings have replaced forgings. The reason governing substitutions has been, generally speaking, the need to rely upon the particular properties inherent in more or less special steel castings. In certain cases, especially carbon steels, there are the methods of manufacture, which are the main cause for substitutions.

Examples from Practice

In the sphere of rolling stock, for manufacture of locomotive bodies, side frames and cylinders, steel castings have been increasing ever since their introduction several years ago, and, moreover, recently there has been the important development in the direction of the use of special steels for brake parts where cast iron has reigned supreme until now. Nickel-chrome-molybdenum steel brake drums are now largely used for rail cars, heavy lorries and even for certain brake shoes, where special cast steels are now in the course of development. In such cases, there are questions of the mechanical properties at elevated temperatures, for temperature becomes increasingly important with the constant increase in speeds.

So far as material for rolling stock is concerned, steel castings are almost completely used in the manufacture of wheel centres for heavy lorries and tractors, a field which had been usurped by wheels of the disc variety, when solid tyres were replaced by pneumatic ones for heavy vehicles. It should be pointed out, however, that this return to the making of wheel centres as steel castings, is not yet so developed in France as in America, England and Italy. It is, however, receiving serious consideration. This evolution introduces new designs for the fixing of rims, brake drums and other important components from the time since 10-ton and even larger vehicles have constantly attained speeds of 30 miles an hour on the road.

Crankshafts

Before leaving this question of motor vehicles, it seems desirable to refer to the new idea of replacing forged crankshafts by those made as castings. The alloy used in the case of the most widely known application (Ford) is an intermediary alloy between iron and steel. This new application is claimed simultaneously by both the iron and steel founder. One thing, however, is certain, that the melting methods used, as well as the moulding methods, belong more to the steel than to the iron foundry. However this may be, if such solutions develop in the case of other types of engines, it is perfectly certain that the gain to the foundry industry in general will be of a really important character.

In an entirely different field, but one quite capable of supporting large tonnages, it is interesting to point to the use by certain large steelworks of steel ingot moulds in the place of those made in iron. It is, of course, a rather unique application and one which will be for a long time the subject of much controversy, but, for the moment, probably from a spirit of emulation, a certain amount of progress has been registered, especially in the East of France.

Stainless and Special Steels

As for the question of chemical corrosion, there has always been a fierce fight between the forging and casting; the latter clearly shows advantages in the direction of cost for short runs, but it is obviously handicapped by surface defects in cases where finish and polish is required. Questions of heat resistance are always more or less complicated by considerations of chemical corrosion, and in this direction steel castings have frequently replaced more or less special cast irons. There is, on the other hand, a tendency for simple forms of steel castings to be replaced by steels of the same type, but rolled and welded. A typical example is given by annealing boxes which are often fabricated from sheet. Reference should also be made, whilst referring to stainless steels, to the replacement in not a few cases of copper alloys by steel castings. It often occurs in the case of plumbers' brass foundry ware, and under experimental conditions for ships' propellers. A special field, recently opened up to steel castings, is that of permanent magnets, where new compositions, containing nickel and aluminium, have shown remarkable progress in recent years. The reasons for choosing castings in this case are first of all the form of certain magnets, and, above all, the fact that these steels are only forgable with difficulty.

Welding *versus* Castings

Reference must now be made to the controversy between castings and welded structures. It is true to say that the substitution of welded assemblies for castings refers to more or less, but probably more, to iron castings than to steel, and, in the first case, the steel foundry generally gains thereby. It is, however, very rare that it is possible to show a complete advantage through the welding of rolled steel into assemblies destined to replace iron castings. It is, in most cases, important to mould certain constituent parts of these assemblies (pipes with branches, etc.), and these parts are obviously made out of steel castings. When there is a case of replacement of one-piece steel-casting by a welded assembly, it is both logical and economical that part of it should be made as a casting. The final story of the technological properties of weldings has yet to be written and such questions as the resistance to fatigue by welds and the fractures which have been noted in service, have perhaps been over-emphasised. Unquestionably, some progress has been made, and the final outcome must be that of close co-operation between the welder and the foundryman.

The obtaining of reliable welds between castings on the one hand, and rolled sections on the other, is not easy. It implies for the first, qualities of steel which are not too common, that is, those of very low silicon-content. Very few foundries are capable of producing such a material, and this definitely creates a special sphere where one can only succeed if he possesses the greatest aptitude, especially from the metallurgical point of view. As pointed out above, steel castings do not seem to be in too bad a position from the point of view of recent developments and have not been subjected to great sacrifices. So far as the future is concerned, it is difficult to prognosticate, but it seems that a number of favourable factors are obvious. Steel castings are logically bound to benefit, to a greater or less extent, from increases of speeds, of pressures, and from demands of all kinds which characterise the modern evolutions of engineering, and, above all, from certain attempts at weight reduction, if, of course, foundry technique keeps pace with engineering developments. This technique has already made marked progress in the course of the last few years, not only from the purely metallurgical point of view, but also from the raw materials aspect, from design and mould construction, from the lay-outs of runners and risers and of feeding, and, finally, from the control of the finished casting. So far as pure and simple design is concerned, the tendency of engineers to demand from the steel founder more than he is capable of performing, and the important set-backs which have resulted therefrom, actually leads more quickly perhaps than for other foundry specialities to a fruitful collaboration between designer and foundryman. The recent tendency characterised by certain welded assemblies leads to the thought of dividing up castings which are too complicated, and it is not thought to be in the interest of steel foundrymen to discourage it, for it should lead, through successive improvements, to the assembling by welding of relatively simple moulded parts where it would not be possible to guarantee the quality of a single cast unit. Several examples of this kind are actually in the course of development.

* Paper read before the International Foundry Congress held in Paris. The author is assistant director of the Paris Foundry High School.

Zirconium

The element zirconium has many uses in industry, of which by far the principal is as a refractory in the lining of electric furnaces, crucibles and combustion tubes. It is employed to harden steel and combined with carbon as an abrasive. The following notes on Brazilian zirconium are taken from the "Mineral Trade Notes" issued by the United States Bureau of Mines.

At present Brazil is the chief world source of zirconium. In 1936 the total exports to all countries were 2,273 metric tons, against 1,780 tons in 1935. Zirconium ore exports to various countries in 1936, in metric tons, were divided as follows:—United States, 687; Germany, 690; Norway, 532; France, 181; Holland, 104; Great Britain, 43; Belgium, 25; and Italy, 11 tons.

The native zirconia of Brazil, known as baddeleyite, contains up to 99 per cent. ZrO_2, 80 per cent. brazilite, and up to 50 per cent. zirkelite (zirconium silicate). These minerals are known as zirconium-oxide types, which is the form in which it is mined commercially in Brazil. The monazite and ilmenite sands in the State of Espirito Santo and Bahia, which contain only about 7 per cent. zirconium, are called the zircon type. Other types of this mineral, the acid and tantalate types, are not found in Brazil. The Brazilian ores from which zirconium is obtained may be classed as three kinds, according to their occurrence, namely:—(1) "Favas" or pebbles; (2) alluvial or rolled ores; and (3) ore in veins. By far the greater quantity is of the second class. The favas contain 90 to 93 per cent. zirconium and the other type 70 to 90 per cent.

In Brazil the main deposits are in the Pocos de Caldas district in the States of Minas Geraes and Sao Paulo, about 390 km. north by rail from the nearest seaport, Santos. Here seven deposits extend over a distance of 27 km. in a south-easterly direction from the railway station at Cascata. This district is in a plateau having an average elevation of 3,600 ft. Recent estimates place the reserves of zirconium ore in Brazil at a total of 1,790,000 tons. In the monazite fields of the States of Espirito Santo, Minas Geraes, and Rio de Janeiro, mixed in with the monazite and ilmenite alluvial sands, is a good percentage of zircon (silicate) sand that would add a considerable quantity to the reserves of zirconium-bearing ores in the Republic. Prior to the war zircon silicate sand was the chief source of zirconium compounds.

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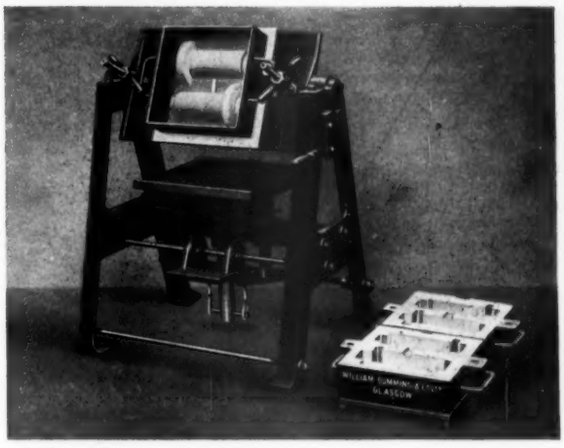

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This Week's News in Brief

Trade Talk

Notice is given of the release of the liquidator of **Widnes Foundry (1925), Limited, 121, Lugsdale Road, Widnes, Lancashire.**

Swan, Hunter & Wigham Richardson, Limited, Wallsend, have received an order for an 8,300-ton steam tanker for Trinidad Leaseholds, Limited, London.

Sir W. G. Armstrong Whitworth & Company (Ironfounders), Limited, have changed their London office from Thames House, Millbank, to Abbey House, 8, Victoria Street, S.W.1.

J. L. Thompson & Sons, Sunderland, have received an order from the Silver Line for a 9,800-ton turbine-driven steamship. The engines will be built by the Wallsend Slipway & Engineering Company, Limited, Wallsend.

The North-Eastern Marine Engineering Company, Limited, Wallsend, are to build the propelling machinery for a 9,250-ton ship, to be built by the Caledon Shipbuilding Company, Limited, Dundee, for Watts, Watts, Limited.

John Hastie & Company, Limited, Kilblain Engine Works, and Caledonian Foundry Company, Limited, Greenock, have acquired the stock in trade, plant and goodwill of Barr & Company, Limited, non-ferrous founders, of Greenock.

Grahamston Iron Company, Limited, Falkirk, have taken over the entire share capital of Summerford Iron Company, Limited, Camelon. Both foundries specialise in the manufacture of light castings, and new plant is to be installed in the Summerford Iron Company's shops.

Metal Industries, Limited, who have salvaged the 25,000-ton ex-German battleship "Friedrich de Grosse" from Scapa Flow, finally moored the ship at their Rosyth dockyards on August 5 for breaking up. The company is now attempting to raise the 25,000-ton battleship "Grosser Kurfurst" from Scapa Flow, and is also negotiating for the American liner "Leviathan," which will be broken up.

The British Iron and Steel Corporation has addressed a letter to the Minister of Health in regard to the collection of household scrap iron, in which it is pointed out that, owing to the cost of collection, persons having small quantities to dispose of cannot expect to receive value for the scrap other than in the form of free removal. The response to the campaign for the collection of waste iron and steel has been tremendous, and it would be a great pity if the public spirit shown on all hands were to be prejudiced by misconception as to the price which it is economically possible to offer for old iron at the house, farm or factory. Thanks to the arrangements concluded between the Corporation and the scrap merchants, everyone may be satisfied that the old iron cleared from his house or yard does go direct to a British steelworks and not, as it might have done in the past, to a foreign country. It was perhaps inevitable that many people should assume from the fact that the scrap campaign was considered opportune, that what might be termed a "scarcity" price could be expected. While, strictly speaking, no famine of iron and steel scrap exists, the industry is in need of the waste material lying in houses and factories, and the Corporation believes that, if the public were aware that the cost of collecting one or two hundredweights of old iron at a time generally extinguishes its worth to the collector, they would not ask for value other than in the form of free removal.

Company Reports

Shanks & Company, Limited.—Interim dividend on the ordinary shares of 3 per cent., less tax, for the year ended December 31 last.

National Gas & Oil Engine Company, Limited.—Interim dividend of 2½ per cent. on the preference shares for the six months to June 30.

Mr. J. H. G. Monypenny has been elected chairman of the British Chemical Plant Manufacturers' Association for the third year in succession. Mr. Monypenny is associated with the firm of Brown Bayley's Steel Works, Limited, Sheffield.

Personal

Mr. W. Haynes, secretary, and Mr. O. Wans, chief engineer, have been elected directors of Ruston & Hornsby, Limited, Lincoln.

Mr. J. G. Goodenough, general manager of Dorman, Long & Company, Limited, Middlesbrough, has been elected to the board of directors of the company.

Mr. John Johnstone, who has spent the whole of his working life with Glenfield & Kennedy, Limited, Kilmarnock, received a presentation from the employees when he retired recently.

Lord Dudley G. Gordon, President of the British Engineers' Association, has been appointed chairman of the honorary committee of experts of the Engineering and Marine Exhibition, in succession to Dr. H. S. Hele Shaw, who has resigned.

Mr. Desmond A. Smith has been appointed chairman of Borax Consolidated, Limited, in succession to the Earl of Leven and Melville, who has resigned. Mr. A. H. Reid has been elected to the board to fill the vacancy caused by the death of Mr. R. C. Baker.

Mr. Clifford C. Paterson, O.B.E., M.Inst.C.E., M.I.E.E., F.Inst.P., director of the research laboratories of the General Electric Company, Limited, has had conferred on him by Birmingham University an honorary degree of doctor of science. Dr. Paterson was for 16 years a member of the staff of the National Physical Laboratory, where he established and administered the electrotechnics and photometry divisions of the Laboratory until 1918. He then accepted the task under Lord Hirst of initiating the G.E.C. laboratories at Wembley.

Dr. James T. MacKenzie, chief metallurgist of the American Cast Iron Pipe Company, Birmingham, Ala., has been selected by the American Foundrymen's Association to present the Association's Exchange Paper at the next annual conference of the Institute of British Foundrymen. His Paper will review research work on chemical changes of cast iron in cupola melting. At the annual convention of the American Foundrymen's Association this year, Dr. MacKenzie was awarded the J. H. Whiting gold medal for important and practical work in the advancement of grey-iron foundry practice.

Obituary

Mr. Dugald Cameron, a director of the Singer Manufacturing Company, Limited, has died.

Mr. William Wallace, who for over 20 years was manager at Ayr for John Wallace & Sons, Limited, Glasgow, and later was managing director of John Wallace & Son (Ayr), Limited, died on August 6. Five years ago, with his son, he started business on his own account in Ayr, and was the originator of several agricultural implements.

The Rt. Hon. John Hodge, the first Minister of Labour, and afterwards Minister of Pensions, died at Bexhill on Tuesday, at the age of 81. He was for more than 45 years actively associated with trade unionism in the iron and steel industry. It was in 1886, at Motherwell, where Mr. Hodge was then working as a steel melter, that he founded an organisation of 66 workers which, within two years, established numerous branches in Scotland, England and Wales under the title of the British Steel Smelters' Association. Mr. Hodge acted as secretary of this new body, and in 1902 was President of the Trades Union Congress. In the war period he played a leading part in the creation of the British Iron, Steel and Kindred Trades Association (in 1917), and when this in turn formed the Iron and Steel Trades Confederation, Mr. Hodge became President of both, and maintained an active interest in their affairs until he retired in 1931. As a politician, he entered the House of Commons as one of the original Labour members who formed the Parliamentary Labour Party in 1906. For 17 years he was member for the Gorton (Manchester) division, resigning at the general election in 1923. He was made Minister of Labour—a newly created office—in the second coalition government, 1916-17, and was Minister of Pensions from 1917 to 1919.

Company Meetings

Head, Wrightson & Company, Limited

Presiding at the annual meeting of Head, Wrightson & Company, Limited, held recently at Teesdale Ironworks, Thornaby-on-Tees, Sir Guy Wrightson, Bt., said that a new issue of ordinary shares had been successfully completed, part of the proceeds being included in the present balance-sheet. In spite of the two waves of depression which came upon the engineering and heavy industries, he thought they might claim to have come through satisfactorily having regard to all the circumstances, particularly from the point of view of their debenture-holders, staff and men. They were also pleased that they had been able to pay the arrears of preference dividend and to resume payment of dividends on the ordinary shares. They had had no fresh capital in the company for 30 years, extensions and improvements having been provided out of past profits; consequently it was not surprising that their expansion last year was hampered by lack of working capital, and for this reason the issue of additional capital was obviously necessary. The profits for this year had also been somewhat affected by having to overtake repairs and maintenance deferred from past years. All departments were working to capacity, and the additional machinery installed enabled them to manufacture under much-improved conditions the new specialities they had undertaken. They commenced the present year with a healthily-balanced order-book, comprising both home and export work, both in capital and consumable products. All they now required for a continuance of good trade was confidence and stability in the world's currency standards and the prosperity of the other countries who bought from them.

Armstrong Whitworth Securities Company, Limited

The annual meeting of Armstrong Whitworth Securities Company, Limited, was held in London on Friday, July 30. Mr. C. Bruce Gardner (chairman), who presided, recalled that last year as a result of an agreement entered into between the Government and the railway companies, special financial facilities were arranged to the extent of some £30,000,000 in order that the railway companies might put in hand special work which was to anticipate the ordinary railway programme. As a result of these arrangements they had received an order for 227 locomotives and tenders from the London Midland and Scottish Railway Company and 10 locomotives from the London and North Eastern Railway Company. The pneumatic tool department had continued to expand. In the general engineering department they continued to search out and cater for additional classes of work. The results of the Ironfounders Company for the year showed an improved position on last year's results; both in the manufacture of rolls and special refined iron they more than maintained their position in the trade. On general iron castings they were still short of work and prices were low. On the other hand, prices of their raw materials showed considerable advance in price, adding materially to costs. Taking all departments together, the number of men employed was greater than it had been for a very long time and the financial results for the year were very much better. The foundry results were helped by the castings made for the L.M. & S. Railway locomotives built at Scotswood.

Contracts Open

Copenhagen, August 27.—Electrically-driven boiler-feed pump set, for the Copenhagen Lighting Department. The Department of Overseas Trade. (Reference T.Y. 18046/37.)

Melbourne, September 6.—One electrically-driven centrifugal pump and spare parts, for the Melbourne City Council. The Department of Overseas Trade. (Reference T.Y. 25943/37.)

Southport, September 10.—Supply and erection of steelwork and supporting cast-iron piles, for the Borough Council. The Borough Engineer, Town Hall. (Fee £3 3s., returnable.)

Forthcoming Event

SEPTEMBER 16 TO OCTOBER 2.

Engineering and Marine Exhibition:—Incorporating the Foundry Trades' Exhibition and the Welding Exhibition, at Olympia, London, W.14.

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Raw Material Markets

Holidays at the producing end, which are not yet over, are being made as short as possible, and as soon as essential repairs have been carried out plant is again being put into operation. New business is not particularly heavy at the present time, but no anxiety is felt, as order-books are filled for months ahead. It is expected that inquiries will be coming in on a heavier scale in the early autumn.

Pig-Iron

MIDDLESBROUGH.—There has been some expansion in the tonnage of pig-iron sent abroad during the past week, but this trade involves contracts arranged months ago only and no fresh inquiries can be accepted, despite the very attractive prices offering. Home trade also is restricted by the meagre tonnage available, and consumers are having considerable difficulty in procuring their full contract deliveries. Hopes are expressed that a few extra blast furnaces may be put on to the production of Cleveland foundry iron in the near future. Although this would be only a temporary measure, it would be none the less welcomed. All business is transacted on the basis of 101s. per ton for No. 3 Cleveland G.M.B., delivered in this area. Makers of hematite have little surplus material available after current requirements have been met, and little opportunity is provided for the reduction of delivery arrears. The export demand remains heavy and a fair tonnage has been despatched against earlier inquiries; in addition, a small amount of new business has recently gone through.

LANCASHIRE.—The pressure for deliveries is somewhat less insistent at the moment. The supply of common irons to the foundries does not improve, and complaints in this respect are numerous, although of little avail, as makers are not in the position to increase outputs. There appears to be, however, a welcome change with regard to hematite, and there have recently been cases of producers offering small tonnages for early delivery. For delivery to Manchester and district, Derbyshire and Staffordshire brands of No. 3 foundry iron are quoted on the basis of 109s., with Northamptonshire at 107s. 6d. and Derbyshire forge iron at 104s. to 106s., according to the class of consumer. West Coast hematite is quoted at 131s. and East Coast material at 130s. 6d., with Scottish No. 3 foundry nominal at 137s. 6d. per ton.

MIDLANDS.—While there is no actual shortage of pig-iron at the present time, a stringency is expected to result in the autumn, when the demand increases. In view of this fact, a fair tonnage of American low-phosphoric and Continental high-phosphoric iron has been contracted for by consumers in this district. For delivery to Birmingham and Black Country stations, No. 3 foundry pig-iron is quoted at 103s. 6d. for Northamptonshire, and 106s. for Derbyshire, Lincolnshire and North Staffordshire. The inquiry for special irons has been well maintained. Low-phosphorus iron is quoted at from £6 10s. to £7 5s., while refined iron is quoted at a minimum of £8 2s. 6d. Makers generally are unwilling further to increase their commitments with regard to hematite; supplies are on the short side. East Coast No. 3 is quoted at £6 13s. 6d. and West Coast mixed numbers at £6 14s. 6d. per ton, delivered to stations in the Midland area.

SCOTLAND.—Activity in this area is well maintained and further big orders have recently been received by the heavy industries, including railway equipment, constructional, bridge and tank work and various kinds of Government orders. The demand for pig-iron shows no sign of slackening. No. 1 foundry is quoted at 115s. 6d. and No. 3 at 113s. With regard to Cleveland iron, nothing at all was shipped from the Tees to Scotland during the month of July. Cleveland No. 3 is quoted at 104s. f.o.t. Falkirk and 107s. f.o.t. Glasgow, but these prices are purely nominal. Local steelworks are working to capacity and are taking up every ton of pig-iron which they can procure. Mixed numbers of hematite are quoted at 123s.; with Scottish basic, 107s. 6d., English basic, 100s., and Indian basic, 100s., delivered f.o.t. steelworks.

Coke

The price of Durham foundry coke now varies from 51s. 6d. to 56s. for delivery to the Midlands, while Welsh coke prices are from 52s. 6d. to 65s. Most makers refuse to take orders beyond the end of the year, while others stipulate the end of September.

Steel

Quiet conditions, largely due to holiday causes, rule in the steel market, and are likely to prevail for the next few weeks, states the official report of the London Iron and Steel Exchange. Apart from the holidays business is inactive, since new transactions are severely limited by the inability of the makers to accept orders except for very extended delivery. Output is maintained at a high rate, but is immediately absorbed by the consuming industries. The arrangements, however, which have been made to supplement the home production by imports of Continental steel should help to relieve the situation in the autumn. In the semi-finished steel department, the demand continues to outstrip the supply, although the British works making this class of material are working to capacity. The demand for finished steel, particularly structural descriptions, is unrelaxed, and the manufacturers are concentrating upon the execution of urgent orders. The export demand is maintained, but only a proportion can be satisfied owing to the heavy home requirements.

Scrap

Home production of scrap, although increased, is still inadequate fully to meet the demand and imports from the Continent and the United States are on a heavy scale. Very high prices naturally have to be paid for imported scrap. As a result of the intensified search for scrap under the auspices of the British Iron and Steel Corporation, better supplies have come on to the market. Prices are being firmly maintained.

Metals

Conditions have been firm following a resumption of business in the non-ferrous metal markets after the holiday, and a fairly good tonnage has changed hands.

Copper.—The weekly market report issued by Brandeis, Goldschmidt & Company, Limited, states that "when dealings were resumed on the London Metal Exchange after the Bank Holiday, the market was quiet, but the undertone remained firm. Towards the close of the week there was a renewal of buying on a market on which—owing to the small speculative position—there were few sellers. This buying was prompted by firm advices from America, while a general improvement in the French situation led to a better demand on the Continent. Buyers of forward electro have, however, found little inducement to purchase, owing to the very large margin which still obtains between standard copper and electro copper. Consequently, sales for later than beginning of October shipment have not been considerable." The copper price question has been revived in the United States. It has been suggested that a rise of 50 points will be made on the current quotation of 14 cents. An effort to increase the price was made some time ago, but this was thwarted by the refusal of one big producing concern to come into line.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £58 5s. to £58 6s. 3d.; Friday, £59 5s. to £59 7s. 6d.; Monday, £60 5s. to £60 7s. 6d.; Tuesday, £59 5s. to £59 6s. 3d.; Wednesday, £58 15s. to £58 17s. 6d.

Three Months.—Thursday, £58 6s. 3d. to £58 7s. 6d.; Friday, £59 8s. 9d. to £59 10s.; Monday, £60 10s. to £60 11s. 3d.; Tuesday, £59 8s. 9d. to £59 10s.; Wednesday, £58 18s. 9d. to £59.

Tin.—According to the monthly tin statistics compiled by Mr. W. H. Gartsen (Henry Rogers, Sons & Company) the total visible supply of tin on July 31 was 20,150 tons, as compared with 17,304 tons at the end of June and 13,000 tons on July 31, 1936. The carry-over in the Straits Settlements was 3,610 tons, against 3,761 and 2,142 tons respectively, while the carry-over at the Arnhem (Holland) smelter was 1,282 tons, as compared with 1,374 and 822 tons respectively. The heavy rise in visible supplies had not been expected, and was caused through some 2,000 tons being held up in New York docks resulting in small deliveries in the United States. A. Strauss & Company, Limited, in their monthly review of the market position, state that "it may be that the industrial unrest in the United States is, in part, responsible for this accumulation of metal in New York, in that the sporadic strikes and lock-outs affecting one plant after another have made it desirable to hold supplies at one centre, where they can be distributed according to need. It is probable that most of this metal will be delivered during coming weeks." Speaking of the buffer pool proposal, to which it is strongly opposed, the firm observes that the discussion on this subject is at the moment theoretical. Every producing country, it says, with the exception of Malaya, is behindhand with its production quota, and minehead stocks are everywhere abnormally small. It will be very many months before production can rise sufficiently to establish an adequate visible supply, let alone to make the formation of any sizeable reserve stocks, either in a central pool or in producers' hands, a practical proposition. Criticism of Government apathy in regard to the future of tin restriction was made in a farewell speech by Mr. A. H. Flowerdew, a leading member of the Malayan mining community, who is returning to England on retirement. The question of the future renewal of tin restriction, Mr. Flowerdew declared, would be fought out on the basis of potential output, in which it seemed Malaya was suffering a severe lag. He thought the Government ought to consider this point with the utmost care if it was their policy to maintain Malaya as a first-class power in the tin world.

Official quotations were as follow :—

Cash.—Thursday, £267 15s. to £268; Friday, £270 to £270 10s.; Monday, £270 10s. to £270 15s.; Tuesday, £268 to £268 5s.; Wednesday, £266 5s. to £266 15s.

Three Months.—Thursday, £265 10s. to £265 15s.; Friday, £267 15s. to £268; Monday, £268 5s. to £268 10s.; Tuesday, £266 10s. to £266 15s.; Wednesday, £264 to £264 5s.

Spelter.—A good tone has prevailed in this market during the past week and the quotation has remained in excess of the price of lead. It is understood that American buyers have purchased considerable supplies from London recently, owing to the acute shortage of zinc in that country. The shortage has caused the domestic quotation to be raised from 7 cents per lb. to 7.25 cents. It is thought likely that the import duty of 25 per cent. will be reduced or even abolished.

Daily market prices :—

Ordinary.—Thursday, £23 16s. 3d.; Friday, £25 1s. 3d.; Monday, £25 18s. 9d.; Tuesday, £25 10s.; Wednesday, £25 2s. 6d.

Lead.—The shortage of structural steel, which has, to some extent, caused the pronounced decline in the building trade, is likely to have an adverse effect on the lead market in addition to the light-castings makers, who already have felt the decrease in building specifications. The market has been quite firm recently, while in the United States the strong tone has resulted in an advance of 25 points in the domestic price to 6.25 cents per lb. New York.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £23; Friday, £24; Monday, £24; Tuesday, £23 6s. 3d.; Wednesday, £22 15s.

Scrap.—There has again been rather a quiet tone in the scrap market, but the demand is likely to increase in the near future and some good business is to be expected.

Approximate selling prices for old metal :—New aluminium cuttings, £82; rolled, £67; cast, £43; foil, £94 to £98. Copper, £52 to £56; braziery, £49. Brass (clean), £33 to £37. Zinc, £15. Lead, £22 10s. Gunmetal, £52 to £54.

Goods by Road

The question of motor transport for castings is of very considerable importance and the issue of a reliable guide certainly fulfils a long-felt want. The one we have received is issued by the Transport Publishing Company, 38, John Street, Birmingham, 1. It is sold at 2s. 6d. and covers all the main town to town services. The system employed has been to list the towns alphabetically and the services radiating from them are placed immediately below, together with a reference to a numerical list. The list gives the names of the firms and their telephone numbers.

There are various grades of YORKSHIRE SAND

Yorkshire Sand is of a synthetic nature, its production being under careful laboratory control. Perfect standardization is obtained with the various grades, suitable for light and the heaviest steel castings.

It is because of the refractability of the sand and of the toughness of the mould surface that castings made with Yorkshire Sand are distinguishable by their excellent finish.

YORKSHIRE SAND

for "easy stripping"

Information regarding the most suitable grades of Yorkshire Sand for your particular needs and full technical details will be given without obligation.

SOLE PRODUCERS

GENERAL REFRACTORIES LTD.,

TELEPHONE: SHEFFIELD 31113 (6 LINES)

Genefax House, Sheffield

TELEGRAMS: "GENEFAX, SHEFFIELD"

LONDON OFFICE: Russell House, Adelphi, W.C.2. Telephone: Temple Bar 361 Telegrams: "Genefax, Rand-London" (Mr. A. C. Turner)

SCOTTISH OFFICE: 48, West Regent Street, Glasgow. Telephone: Douglas 6108 Telegrams: (3 lines) "Genefax, Glasgow" (Mr. C. A. G. Thomson)

SWANSEA OFFICE: Metropole Chambers, Wind St., Swansea. Telephone: 3680 Telegrams: "Genefax, Swansea" (Mr. D. F. Hood-Williams)

MANCHESTER OFFICE: 9, Albert Square, Manchester, 2. Telephone: Blackfriars 6130 Telegrams: "Genefax, Manchester" (Mr. S. G. Throssell)

MIDDLESBROUGH OFFICE: Halifax Bldgs, Exchange Place. Telephone: Middlesbrough 3313 Telegrams: "Genefax, Middlesbrough"

CARDIFF OFFICE: 17, Windsor Place. Telephone: 5796 Telegrams: "Genefax, Cardiff" (Mr. F. E. Rutter)

Other Moulding Sands include—Zenith Red Sand, York Yellow 102 Sand, Scottish Rock Sand, Bramcote Red Sand, Harperley Sand, Hensall Sand, Red Rover Sand, Warsop Sand, Mansfield Sand.

RAW MATERIALS—PRICE LIST

(Wednesday, August 11, 1937)

COPPER

	£	s.	d.
Standard cash	58	15	0
Three months	58	18	9
Electrolytic	65	10	0
Rough	64	15	0
Best selected	65	5	0
Sheets	96	10	0
India	75	15	0
Wire bars	66	10	0
Ingot bars	66	10	0
H.C. wire rods	70	0	0
Off. av. cash, July	56	9	$4\frac{7}{44}$
Do., 3 mths., July	56	8	$2\frac{9}{11}$
Do., Sttlmnt., July	56	9	$2\frac{5}{11}$
Do., Electro, July	63	10	$2\frac{5}{11}$
Do., B.S., July	63	12	6
Do., wire bars, July	64	4	$3\frac{9}{11}$
Solid drawn tubes			$14\frac{1}{2}$d.
Brazed tubes			$14\frac{1}{2}$d.
Wire			$10\frac{1}{2}$d.

BRASS

Solid drawn tubes	$12\frac{1}{2}$d.
Brazed tubes	$14\frac{1}{2}$d.
Rods, drawn	$11\frac{1}{2}$d.
Rods, extd. or rlld.	$7\frac{1}{2}$d.
Sheets to 10 w.g.	$10\frac{1}{2}$d.
Wire	10d.
Rolled metal	$9\frac{3}{4}$d.
Yellow metal rods	$7\frac{1}{2}$d.

TIN

	£	s.	d.
Standard cash	266	5	0
Three months	264	0	0
English	266	10	0
Bars	268	5	0
Straits	267	15	0
Eastern	266	15	0
Banca (nom.)			—
Off. av. cash, July	263	14	$1\frac{1}{11}$
Do., 3 mths., July	262	6	$8\frac{6}{11}$
Do., Sttlmt., July	263	14	$2\frac{8}{11}$

SPELTER

	£	s.	d.
Ordinary	25	2	6
Remelted	22	10	0
Hard	21	10	0
Electro, 99.9	27	16	3
English	26	10	0
India	22	10	0
Zinc dust	30	0	0
Zinc ashes	8	0	0
Off. aver., July	22	12	$7\frac{4}{11}$
Aver. spot, July	22	11	$4\frac{4}{11}$

LEAD

	£	s.	d.
Soft foreign, ppt.	22	15	0
Empire (nom.)	24	2	6
English	25	0	0
Off. aver., July	23	16	$4\frac{17}{88}$
Aver. spot, July	23	18	$7\frac{7}{11}$

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

Zinc sheets, English	39	0	0 to	39	10	0
Do., V.M. ex-whse.	39	0	0 to	39	10	0
Rods				34	0	0

ANTIMONY

English	82	10	0 to	83	10	0
Chinese, ex-whse.				70	0	0
Crude, c.i.f.				36	0	0

QUICKSILVER

Quicksilver	13	10	3

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—						
25%	14	10	0			
45/50%	12	0	0			
75%	17	0	0			
Ferro-vanadium—						
35/50%	12/8 lb. Va					
Ferro-molybdenum—						
70/75% carbon-free	4/9 lb. Mo.					
Ferro-titanium—						
20/25% carbon-free	9d. lb.					
Ferro-phosphorus, 20/25%	£21 to £22					
Ferro-tungsten—						
80/85%	5/- to 6/- lb.					
Tungsten metal powder—						
98/99%	5/- to 6/- lb.					
Ferro-chrome—						
2/4% car.	34	15	0			
4/6% car.	24	5	0			
6/8% car.	24	0	0			
8/10% car.	24	0	0			
Ferro-chrome—						
Max. 2% car.	36	0	0			
Max. 1% car.	38	5	0			
Max. 0.5% car.	41	0	0			
70% carbon-free	10d. lb.					
Nickel—99.5/100%	£180 to £185					
"F" nickel shot	£165	0	0			
Ferro-cobalt, 98/99%	8/6 to 8/9 lb.					
Metallic chromium—						
96/98%	2/5 lb.					
Ferro-manganese—						
76/80% loose	£18	15	0 to 19	5	0	
76/80% packed	£19	15	0 to 20	5	0	
76/80% export	£22	0	0			
Metallic manganese—						
94/96% carbon-free	1/3 lb.					

Per ton unless otherwise stated, basis 2-ton lots.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 7d.
Finished bars, 18% tungsten	3s. 6d.

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under $\frac{1}{2}$ in. to $\frac{1}{4}$ in.	3d. lb.
Do., under $\frac{1}{4}$ in. to $\frac{1}{16}$ in.	1/- lb.
Flats, $\frac{1}{4}$ in. × $\frac{1}{2}$ in. to under 1 in. × $\frac{3}{4}$ in.	3d. lb.
Do., under $\frac{1}{4}$ in. × $\frac{1}{2}$ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£	s.	d.	£	s.	d.
South Wales (West)—						
Heavy steel, best	3	7	6 to	3	10	0
Mixed iron and steel	3	5	0 to	3	7	6
Heavy cast iron	3	8	0 to	3	10	0
Good machinery				4	0	0
Cleveland—						
Heavy steel, best	3	6	6 to	3	9	0
Steel turnings				2	15	0
Heavy cast iron				4	7	6
Heavy machinery				4	10	0
Midlands—						
Short heavy steel	3	17	6 to	4	0	0
Light cast-iron scrap				3	5	0
Heavy wrought iron	4	0	0 to	4	5	0
Steel turnings	2	2	6 to	2	5	0
Scotland—						
Heavy steel, best	3	4	6 to	3	7	0
Ordinary cast iron				4	7	6
Cast-iron borings	2	0	0 to	2	2	6
Wrot-iron piling	4	13	6 to	4	15	0
Heavy machinery	4	13	6 to	4	15	0

London—Merchants' buying prices, delivered yard.

Copper (clean)	49	0	0
Brass	32	0	0
Lead (less usual draft)	20	10	0
Tea lead	14	10	0
Zinc	16	0	0
New aluminium cuttings	74	0	0
Braziery copper	44	0	0
Gunmetal	46	0	0
Hollow pewter	170	0	0
Shaped black pewter	130	0	0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	103/6
,, No. 3	101/-
,, No. 4	100/-
Forge No. 4	100/-
Hematite No. 1	123/-*
Hematite M/Nos.	122/6*
N.W. Coast—	
Hem. M/Nos. d/d Glas.	123/-*
,, d/d Birm.	134/6*
Malleable iron d/d Birm.	160/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	103/-
,, No. 3 fdry.	106/-
Northants forge	100/6
,, fdry. No. 3	103/6
,, fdry. No. 1	106/6
Derbyshire forge	103/-
,, fdry. No. 3	106/-
,, fdry. No. 1	109/-
Scotland—	
Foundry, No. 1, f.o.t.	115/6
,, No. 3, f.o.t.	113/-
Cleveland No. 3, Glasgow	107/-
,, ,, Falkirk	104/-
Scottish hem. M/Nos. d/d	123/-*
Sheffield (d/d district)—	
Derby forge	100/6
,, fdry. No. 3	103/6
Lincs forge	100/6
,, fdry. No. 3	103/6
W.C. hematite	128/6*
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	109/-
Staffs fdry. No. 3	109/-
Northants fdry. No. 3	107/6
Cleveland fdry. No. 3	109/-
Glengarnock, No. 3	137/6
Clyde, No. 3	137/6
Monkland, No. 3	137/6
Summerlee, No. 3	137/6
Eglinton, No. 3	137/6
Gartsherrie, No. 3	137/6
Shotts, No. 3	137/6

* Subject to a rebate of 5s. per ton under certain conditions.

FINISHED IRON AND STEEL

Usual district deliveries.

[A rebate of 15/- per ton for steel sections, plates and joists is obtainable in the home trade under certain conditions.]

	£	s.	d.	£	s.	d.
Iron—						
Bars (cr.)	13	5	0 to	13	15	0
Nut and bolt iron	11	12	6 to	12	2	6
Hoops				14	2	6
Marked bars (Staffs) f.o.t.				15	15	0
Gas strip				14	2	6
Bolts and nuts, $\frac{3}{4}$ in. × 4 in.				17	10	0 and up.
Steel—						
Plates, ship, etc.	11	8	0 to	11	10	6
Boiler plts.	11	18	0 to	12	0	6
Chequer plts.				13	0	6
Angles				11	0	6
Tees				12	0	6
Joists				11	0	6
Rounds and squares, 3 in. to $5\frac{1}{2}$ in.				12	0	6
Rounds under 3 in. to $\frac{1}{4}$ in. (Untested)				11	9	0
Flats—8 in. wide and over				11	5	6
,, under 8 in. and over 5 in.				11	10	6
Rails, heavy				10	2	6
Fishplates				14	2	6
Hoops (Staffs)				12	4	0
Black sheets, 24g. (4-t. lots)				15	15	0
Galv. cor. shts. (,,)				19	10	0
Galv. flat shts. (,,)				20	0	0
Galv. fencing wire, 8g. plain				20	5	0
Billets, soft, 100-ton lots				7	17	6
Sheet bars				7	15	0
Tin bars				7	15	0

PHOSPHOR BRONZE

	Per lb. basis
Strip	$13\frac{1}{2}$d.
Sheet to 10 w.g.	14d.
Wire	$15\frac{1}{2}$d.
Rods	16d.
Tubes	$20\frac{1}{2}$d.
Castings	16d.

Delivery 3 cwt. free.
10% phos. cop. £33 above B.S.
15% phos. cop £38 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½
Wire round—	
to 10g.	1/6½ to 2/1½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/5½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	25.76
No. 2 foundry, Valley	24.00
No. 2 foundry, Birm.	20.38
Basic, Valley	23.50
Malleable, Valley	24.00
Grey forge, Valley	23.50
Ferro-mang. 80%, seaboard	102.50
O.-h. rails, h'y, at mill	42.50
Billets	37.00
Sheet bars	37.00
Wire rods	47.00
	Cents.
Iron bars, Chicago	2.40
Steel bars	2.45
Tank plates	2.25
Beams, etc.	2.25
Skelp, grooved steel	2.10
Steel hoops	2.40
Sheets, black, No. 24	3.15
Sheets, galv., No. 24	3.80
Wire nails	2.75
Plain wire	2.90
Barbed wire, galv.	3.40
Tinplates, 100-lb box	$5.35

COKE (at ovens)

Welsh foundry	42/6
,, furnace	36/-
Durham foundry	38/6
,, furnace	36/-
Scottish foundry	37/6
,, furnace	35/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 per box	25/- to 26/-	
,,	28×20 ,,	51/- to 52/-	
,,	20×10 ,,	36/6 to 36/9	
,,	18¾×14 ,,	26/3 to 26/6	
C.W.	20×14 ,,	22/6 to 23/6	
,,	28×20 ,,	46/- to 46/6	
,,	20×10 ,,	32/- to 32/6	
,,	18¾×14 ,,	23/- to 23/6	

SWEDISH CHARCOAL IRON & STEEL

Pig-iron	£12	0	0 to	£13	0	0
Bars-hammered, basis	£20	0	0 to	£21	0	0
Bars and nail-rods, rolled, basis	£19	0	0 to	£20	0	0
Blooms	£16	0	0 to	£17	0	0
Keg steel	£27	0	0 to	£30	0	0
Faggot steel	£20	0	0 to	£25	0	0
Bars and rods dead soft st'l	£19	0	0 to	£20	0	0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 19.39 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

		£	s.	d.		
Aug.	5 ..	58	5	0	inc.	15/-
,,	6 ..	59	5	0	,,	20/-
,,	9 ..	60	5	0	,,	20/-
,,	10 ..	59	5	0	dec.	20/-
,,	11 ..	58	15	0	,,	10/-

Electrolytic Copper

		£	s.	d.		
Aug.	5 ..	65	0	0	inc.	5/-
,,	6 ..	65	10	0	,,	10/-
,,	9 ..	66	10	0	,,	20/-
,,	10 ..	66	0	0	dec.	10/-
,,	11 ..	65	10	0	,,	10/-

Standard Tin (cash)

		£	s.	d.		
Aug.	5 ..	267	15	0	inc.	100/-
,,	6 ..	270	0	0	,,	45/-
,,	9 ..	270	10	0	,,	10/-
,,	10 ..	268	0	0	dec.	50/-
,,	11 ..	266	5	0	,,	35/-

Tin (English ingots)

		£	s.	d.		
Aug.	5 ..	267	15	0	inc.	100/-
,,	6 ..	270	0	0	,,	45/-
,,	9 ..	270	10	0	,,	10/-
,,	10 ..	268	0	0	dec.	50/-
,,	11 ..	266	10	0	,,	30/-

Spelter (ordinary)

		£	s.	d.		
Aug.	5 ..	23	16	3	inc.	13/9
,,	6 ..	25	1	3	,,	25/-
,,	9 ..	25	18	9	,,	17/6
,,	10 ..	25	10	0	dec.	8/9
,,	11 ..	25	2	6	,,	7/6

Spelter (Electro, 99.9 per cent.)

		£	s.	d.		
Aug.	5 ..	26	10	0	inc.	13/9
,,	6 ..	27	13	9	,,	23/9
,,	9 ..	28	12	6	,,	18/9
,,	10 ..	28	3	9	dec.	8/9
,,	11 ..	27	16	3	,,	7/6

Lead (soft foreign, prompt)

		£	s.	d.		
Aug.	5 ..	23	0	0	inc.	10/-
,,	6 ..	24	0	0	,,	20/-
,,	9 ..	24	0	0	No	change
,,	10 ..	23	6	3	dec.	13/9
,,	11 ..	22	15	0	,,	11/3

Lead (English)

		£	s.	d.		
Aug.	5 ..	25	0	0	inc.	10/-
,,	6 ..	26	0	0	,,	20/-
,,	9 ..	26	0	0	No	change
,,	10 ..	25	10	0	dec.	10/-
,,	11 ..	25	0	0	,,	10/-

AVERAGE MONTHLY PRICES OF STEEL BOILER PLATES IN ENGLAND

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1900	9 5 0	9 5 0	9 7 6	9 10 0	9 12 6	10 5 0	10 5 0	10 5 0	10 5 0	10 0 0	9 15 0	9 15 0	9 15 10
1901	9 5 0	9 5 0	8 15 0	8 10 0	8 10 0	7 10 0	7 15 0	7 15 0	7 15 0	7 15 0	7 15 0	7 15 0	8 3 11
1902	7 7 6	7 0 0	7 12 6	7 12 6	7 12 6	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 9 7
1903	7 10 0	7 10 0	7 15 0	7 5 0	7 5 0	7 5 0	7 5 0	7 0 0	7 0 0	7 0 0	7 0 0	6 17 6	7 3 11½
1904	6 12 6	6 15 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	6 18 11½
1905	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 10 0	7 5 0	8 0 0	8 0 0	7 1 3
1906	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 10 0	8 0 10
1907	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 0 0	8 0 0	8 8 4
1908	7 10 0	7 10 0	7 10 0	7 5 0	7 5 0	7 5 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 3 9
1909	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	6 15 0	6 15 0	6 15 0	7 0 0	7 0 0	7 0 0	7 0 0	6 18 9
1910	7 0 0	7 0 0	7 1 3	7 5 0	7 5 0	7 5 0	7 5 0	7 5 0	7 5 0	7 10 0	7 10 0	7 10 0	7 5 1
1911	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 14 0	7 10 4
1912	7 18 9	8 0 0	8 0 0	8 7 6	8 10 0	8 10 0	8 10 0	8 15 0	8 16 3	9 0 0	9 2 0	9 5 0	8 11 2½
1913	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	8 19 0	8 15 0	8 5 0	7 15 0	7 15 0	8 17 0
1914	7 15 0	7 15 0	7 15 0	7 13 9	7 10 6	7 5 0	7 0 0	8 0 0	8 2 6	8 5 0	8 5 0	8 5 0	7 15 11½
1915	8 14 0	9 10 0	9 17 6	10 10 0	10 10 0	11 0 0	11 0 0	11 0 0	11 0 0	11 4 0	12 0 0	13 0 0	10 15 5½
1916	13 0 0	13 0 0	13 0 0	12 15 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 12 11
1917	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0
1918	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0
1919	13 0 0	15 0 0	15 0 0	15 0 0	19 5 0	19 17 6	21 0 0	21 10 0	21 10 0	21 10 0	21 15 0	23 10 0	18 9 9
1920	26 0 0	28 0 0	28 5 0	28 10 0	29 5 0	30 0 0	30 0 0	30 0 0	30 10 0	31 0 0	31 0 0	31 0 0	29 9 2
1921	30 5 0	29 0 0	25 0 0	25 0 0	25 0 0	23 0 0	21 0 0	20 10 0	19 0 0	17 10 0	16 0 0	14 16 0	22 1 9
1922	14 10 0	14 10 0	14 10 0	14 10 0	14 10 0	13 1 8	13 10 0	12 15 0	12 10 0	12 10 0	12 10 0	12 6 0	13 10 9
1923	12 8 9	13 6 0	14 0 0	14 0 0	14 0 0	14 0 0	13 12 6	13 0 0	13 0 0	13 0 0	13 0 0	13 10 0	13 9 1½
1924	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	14 0 0	14 0 0	13 11 0	13 5 0	13 5 0	13 10 11
1925	13 5 0	13 5 0	13 5 0	13 1 0	12 15 0	12 15 0	12 15 0	11 5 0	12 7 6	11 14 0	11 10 0	11 10 0	12 11 8½
1926	11 10 0	11 10 0	11 10 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 6 3
1927	11 5 0	11 5 0	11 5 0	11 5 0	11 2 6	11 0 0	11 0 0	11 0 0	10 16 0	10 10 0	10 10 0	10 10 0	10 19 0½
1928	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0
1929	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 10 0	10 5 0	10 1 3	10 1 3	10 1 3	10 1 7	10 6 8½
1930	10 2 9	10 3 5½	10 3 9	10 3 9	10 3 6	10 2 6	10 2 6	10 2 6	10 2 2½	9 19 6	9 16 3	9 16 3	10 1 6½
1931	9 15 0	9 15 0	9 15 0	9 10 11	9 6 9	9 5 3	9 7 0	9 7 9½	9 8 9	9 5 9	9 5 6	9 9 6	9 9 4
1932	9 5 0	9 2 6	8 18 6	8 17 6	8 16 6½	8 16 3	8 16 3	8 16 3	8 16 3	8 16 3	8 16 3	8 16 3	8 17 10
1933	8 10 0	8 10 0	8 10 0	8 8 9	8 5 0	8 5 0	8 5 0	8 5 0	8 5 0	8 5 0	8 6 0	8 7 6	8 6 10½
1934	8 8 1½	8 10 7½	8 16 6	8 17 6	8 6 3	8 6 3	8 5 7½	8 5 0	8 5 0	8 5 0	9 5 0	9 5 0	8 11 0
1935	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0
1936	9 5 0	9 5 0	9 5 0	9 5 0	9 8 1½	9 17 6	9 17 6	9 17 6	9 17 6	9 17 6	9 17 6	9 18 1	9 12 7½
1937	10 0 6	10 0 6	10 0 6	10 0 6	11 18 0	11 18 0	11 18 0	—	—	—	—	—	—

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